AD NUMBER
AD915700
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; NOV 1973. Other requests shall be referred to U.S. Army Missile Command , Redstone Arsenal, Alabama 35809.**
AUTHORITY
USAMC ltr, 14 aug 1975

Technical Report RK-CR-73-9

AD915700

LASER RESONATOR MODEL-FINITE DIFFERENCE METHOD

User's Manual - 1 June 1973 through 21 November 1973

Charles South and David B. Rensch
Hughes Research Laboratories
3011 Malibu Canyon Road
Malibu, California 90265

November 1973

Prepared for
Propulsion Directorate, U S Army Missile Research
Development And Engineering Laboratory
U S Army Missile Command, Redstone Arsenal, Alabama 35809

Contract DAAH-1-73-C-0298

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Disposition Instructions

Destroy this report when it is no longer needed. Do not return it to the originator.

Trade Names

Use of trade names or manufacturers in this report does not constitute an official endorsement or approval of the use of such commercial hardware or software.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Hughes Research Laboratories 3011 Malibu Canyon Road Malibu, California 90265	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

LASER RESONATOR MODEL — FINITE DIFFERENCE METHOD

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
User's Manual — 1 June 1973 through 21 November 1973

5. AUTHOR(S) *(First name, middle initial, last name)*

Charles South and David B. Rensch

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1973	203	

8a. CONTRACT OR GRANT NO. DAAH01-73-C-0298	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT, TASK, WORK UNIT NOS.	
c. DOD ELEMENT	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d. DOD SUBELEMENT	

10. DISTRIBUTION STATEMENT Distribution limited to U S Government Agencies only; test and evaluation; November 1973. Other requests for this document must be referred to Commander, U S Army Missile Command, Attn: AMSMI-RKL Redstone Arsenal, Alabama 35809.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U S Army Missile Research Development Engineering Laboratory, U S Army Missile Command, Redstone Arsenal, Alabama 35809

13. ABSTRACT

Three computer programs are described which allow the study of optical properties of two dimensional laser resonators. Two of the programs treat the propagation of an electric field inside an optical resonator (there are two methods for propagating an arbitrary electric field), and couple the propagating fields to a specified laser medium which may be nonuniform, transversely flowing, saturable, and inhomogeneous. The propagation technique includes diffraction effects throughout the laser medium. Both programs provide output beam characteristics and output power. The third program calculates far field beam characteristics for the laser output.

Some of the features offered the user are a restart facility for long runs, arbitrary location of the medium in the resonator cavity, and capacity for mirror tilt on either or both mirrors.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Computer program						
Laser resonators						
Transverse modes						
Nonuniform laser medium						
Laser output power						
Far-field distributions						

UNCLASSIFIED

Security Classification

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

FOREWORD

This manual describes three computer programs designed to study the optical properties of laser resonators. The first two are both Step-by-Step Computer Programs, termed SSCP and SSCP(ECS), where the latter is based on an Expanding Coordinate System. Both programs simulate the propagation of one or more waves between mirrors in a laser cavity, differing primarily in the coordinate system used to describe the propagation. Experience has shown the SSCP(ECS) program to be more efficient in most cases, requiring less computer time and memory to solve equivalent problems, and for this reason only the SSCP(ECS) is fully documented. The SSCP package is documented only in Section I and Appendix C.

The third program is designed to take an output waveform from the laser cavity (computed by one of the two programs above) and propagate it to the far field to determine the resulting intensity distribution. Appendix B contains a complete description of the program, including its mathematical basis and a description of the required input.

This report represents the second of two user's manuals which have been prepared under Contract DAAH01-73-C-0298. The first was a user's guide for laser resonator modeling using the Fresnel integral technique. This work was monitored by William Martin of the Propulsion Directorate.

NOMENCLATURE

Symbol	
AA	Defined by eq. (14)
ASR	π for cylindrical resonators, 4 for square resonators, O for 2-dimensional calculations
c	Speed of light
DIA1, DIA2	Diameter of mirror 1 (output mirror) or mirror 2
DXMIR1, DXMIR2	Mesh spacing at mirror 1 or 2 for x coordinate
G_j	Small-signal gain at j^{th} mesh point
g_1	Resonator parameters defined by eq. (16)
g_2	Resonator parameter defined by eq. (16)
GZERO	Small-signal gain for analytical gain subroutine
I_{2d}	Local flux density for two-dimensional resonator
I_{3d}	Local flux density for pseudo-three-dimensional resonator
K_o	Wave number $(2\pi/\lambda)$
M	Geometric magnification of unstable resonator
NX	Number of propagating field points in x direction
NZ	Number of propagation steps between mirrors
OMEGA1, OMEGA2	1/e truncation distance for mirror edges
RCURV1, RCURV2	Radius of curvature for mirror 1 and mirror 2

Symbol	
REFL1, REFL2	Mirror reflectivity
TLOSS1	Transmission loss for mirror 1
$\underset{\sim}{U}$	Electric field vector
$\hat{U}$	Phasor for electric field $\underset{\sim}{U}$
$U_j{}^m$	Free-space electric field at $x = j\Delta x$ and $z = m\Delta z$
U_{2d}	Electric field in two-dimensional resonator
VR1, VR2	Defined in eq. (15)
x	Transverse coordinate for electric field
XIZERO	Saturation parameter for analytical gain subroutine
XWIDTH	Extent of x dimension at start of each roundtrip
ZLEN	Distance between mirrors
ZLENMD	Gain medium length
ZMDLOC	Distance from mirror 1 to center of gain medium
Greek	
ϵ	$n^2 - 1$
ΔP_{2d}	Power contained in strip of Δx width
Δx	Incremental step size in x coordinate
Δz	Incremental step size in z coordinate
Δn	$n - 1$
Δn_j	$n_j - 1$, where $n \equiv$ refractive index at j^{th} field point
δx	Defined in eq. (7)
λ	Wavelength

Greek

∇^2	Laplacian operator in rectangular coordinates
∇_t^2	Laplacian operator for x coordinate only
ϕ	Angular coordinate for cylindrical resonators
ω	Optical frequency

I. SYSTEM DESCRIPTION

A. Introduction

The purpose of the Step-by-Step Computer Program (SSCP) is to study the optical properties of laser resonators. The optical properties of a laser system are dependent upon many factors which are interrelated in a complicated manner. This makes it impossible for an experimenter to determine the best choice of medium and resonator parameters for producing an optimum output beam without an expensive experimental trial and error analysis or without conducting a realistic analytical study. The SSCP is useful to the experimenter because it can greatly narrow the range of parameters from which he has to choose. By modeling the laser medium and the optical resonator for the device under analysis, he can vary the model parameters which represent physical variables and choose a range of parameters that give the best beam quality.

The experimenter has the choice of making his analytical analysis using the Step-by-Step Computer Program (SSCP) described in this user's manual or the Fresnel Integral Computer Program (FICP) described in the user's manual for the Two-Dimensional Fresnel Integral Computer Program.[1] The choice is dependent upon the size of the resonator's Fresnel Number and the homogeneity of the laser medium. The SSCP must be used for laser resonators with Fresnel numbers larger than sixty, for a transverse flowing medium, when the medium is highly gain saturated, or when significant density variations exist.

The SSCP is a very versatile tool for the experimenter to use in the analysis of large Fresnel number, inhomogeneous laser devices. Once he has optimized the nonoptical parameters to obtain the largest

---

[1] Two-Dimensional Fresnel Integral Computer Program, User's Manual, Hughes Research Laboratories, Contract No. DAAH01-73-C-0298, May 1973.

amount of energy in the medium, he must select an optical resonator which will optimize the far field intensity distribution (in most instances this means obtaining the largest far field flux density). The SSCP will allow the experimenter to couple up to 6 laser waves to a particular laser medium (except for empty cavity calculations the SSCP must be furnished with a kinetics subroutine). The medium subroutine can represent a single line laser system such as a CO_2 laser or a multiline laser such as an HF laser and it must supply saturated gain and refractive index for each local propagating field point. It will accurately account for diffraction of each propagating wave as they propagate through the laser medium. By examining each wave and their composite (obtained from their averaged intensities) the user can determine if the laser will be single or multimode, the total roundtrip loss or gain for each wave, the output power of the laser, the intensity and phase distribution for each wave in both the near and far field, and an averaged intensity distribution for both the near and far field if the laser is operating multimode. All the above information can be both printed and plotted after each roundtrip pass through the resonator (the operator has the option to print and plot after any given roundtrip pass). Furthermore, the user has the option of including mirror tilt, selecting the axial location of the medium inside the resonator, and selecting mirror reflectivity and mirror transmission loss.

The accuracy of the optimization results using the SSCP depends upon how realistically the medium and resonator models describe the actual laser device. Since any model must make certain approximations, the optical properties as predicted by the SSCP will never be in exact agreement with measured results. Therefore, it is important for anyone using the SSCP to understand the techniques used in the analysis and its limitations. In the remainder of this section the techniques used to analyze laser resonators, the type of information available from the SSCP, the limitations of the computer program, and the factors governing input data to the program will be described.

B. Step-by-Step Technique

The approach that is taken to solve for the transverse modes of a laser resonator is one which closely resembles the actual development of the modes from the laser's spontaneous emission. An arbitrary input wave (the SSCP has a choice of a wave with uniform or gaussian amplitude distribution) is propagated back and forth between two resonator mirrors. As the wave traverses between the mirrors it interacts with the laser medium. As it interacts, its amplitude and phase are adjusted according to the gain and refractive index of the medium. This iterative procedure is repeated until a stable solution is obtained. The wave represented by the stable solution is the steady state transverse mode or modes of the laser. A measure of the beam quality is obtained by transforming the steady state solution (near field of the laser) into the far field and comparing it with the resulting far-field distribution for a uniform near-field distribution.

1. Approximate Solution to the Wave Equation

Confining our attention to the case in which orthogonal field polarizations are not mixed by the laser medium, the electric field vector $\underset{\sim}{U}$ within the resonator may be represented by

$$\underset{\sim}{U}(x, z, t) = \underset{\sim}{i}\, \mathrm{Re}[\hat{U}(x, z) \exp(iK_o z - i\omega t)], \tag{1}$$

where $\underset{\sim}{i}$ is a unit polarization vector, K_o is the free-space wave number ($K_o = 2\pi/\lambda$), ω is the optical frequency in rad/sec ($\omega = cK_o$), and the phasor $\hat{U}$ is a complex number depending on the position coordinates x, z. In a laser resonator, $\hat{U}(x, z)$ satisfies the wave equation.

$$(\nabla^2 + K_o^2 n^2)\, \hat{U}(x, z) = 0 \tag{2}$$

where ∇^2 is the Laplacian in rectangular coordinates, and n is the refractive index (contains both real and imaginary terms). By converting the above differential equation into an integral equation and

using the Green's function for the Helmholtz equation, we can obtain the following equation:

$$\hat{U}(x, z + \Delta z) = \hat{U}_o(x, z + \Delta z) \exp\left(i K_o \Delta n \Delta z + 0(\epsilon \Delta z^2/\rho^2)\right) \qquad (3)$$

where $\hat{U}_o(x, z + \Delta z)$ is the resulting electric field after propagating $\hat{U}(x, z)$ through free-space for a distance Δz, $\epsilon = n^2 - 1$, ρ is the shortest characteristic length in the z direction over which the field amplitude or phase changes, and $0(\epsilon \Delta z^2/\rho^2)$ is a truncation error term. In other words, if we know both the electric field $\hat{U}$ and the local refractive index of the medium (assumed to be constant for a distance Δz) in the z plane, and if we know what the free-space electric field $\hat{U}_o$ is in the $z + \Delta z$ plane, we can determine the electric field $\hat{U}$ in the $z + \Delta z$ plane.

In a laser resonator model, the medium as well as the initial propagating field is assumed to be known. Therefore, what remains to be solved is how to determine the free-space electric field at $z + \Delta z$ from a known electric field $\hat{U}$ at z.

2. <u>Propagation Algorithm (Two-Dimensional)</u>

The two-dimensional free-space wave equation assuming constant K_o is written as

$$\left(i2K_o \frac{\partial}{\partial z} + \nabla_t^2\right) \hat{U}_o(x, z) = 0 \qquad (4)$$

where $\nabla_t^2 = \partial^2/\partial x^2$. Using the following difference equations of DuFort and Frankel (Ref. 2)

[2] R. D. Richtmyer and K. W. Morton, <u>Difference Methods for Initial-Value Problems</u>, Interscience Publishers, Second Edition, 1967.

$$\frac{\partial \hat{U}_o}{\partial z} = \frac{1}{2\Delta z}\left(U_j^{m+1} - U_j^{m-1}\right) \tag{5a}$$

$$\frac{\partial^2 \hat{U}_o}{\partial x^2} = \frac{1}{\Delta x^2}\left(U_{j+1}^{m} - U_j^{m+1} - U_j^{m-1} + U_{j-1}^{m}\right) \tag{5b}$$

where

$$\begin{aligned} x &= j\Delta x \qquad 1 \le j \le NX \\ z &= m\Delta z \qquad 1 \le m \le NZ \end{aligned} \tag{6}$$

[Eq. (5) includes both the real and imaginary terms of $\hat{U}_o$.] We obtain after substituting eq. (5) into eq. (4) the following propagation algorithm:

$$\begin{aligned} \hat{U}_j^{m+1} = \frac{1}{1+\delta x^2}\Big[\hat{U}_j^{m-1} &+ i\delta x\left(\hat{U}_{j+1}^{m} - 2\hat{U}_j^{m-1} + \hat{U}_{j-1}^{m}\right) \\ &+ \delta x^2\left(\hat{U}_{j+1}^{m} - \hat{U}_j^{m-1} + \hat{U}_{j-1}^{m}\right)\Big] \\ &+ \text{Truncation Terms} \end{aligned} \tag{7}$$

where $\delta x = \Delta z/\left(K_o(\Delta x)^2\right)$. Equation (7) allows the field at $z + \Delta z$ to be computed from known field values at z and $z - \Delta z$.

The difference method of DuFort and Frankel is explicit and is unconditionally stable (solution always converges independent of δx, and Δz) in unbounded regimes. From experience and an examination of the truncation terms, it has been determined that if $\Delta z \le 0.5K_o(\Delta x)^2$, and Δx and Δz are less than the smallest characteristic length in the x and z directions, respectively, eq. (7) will accurately propagate an arbitrary field through free space with a gain or loss of less than 1 or 2% for each roundtrip pass (the user should note that these errors do not accumulate from pass to pass).

3. Calculation Procedure

The calculation technique for analyzing laser resonators using the step-by-step propagation algorithm given in eq. (7) is very similar to the technique described in Ref. 1; the main difference is the propagation algorithm [Ref. 1 uses a Fresnel integral to propagate the electric field back and forth in the resonator, while here propagation is accomplished using the numerical difference technique in eq. (7)].

The approach taken is to consider a propagating wave or waves reflecting back and forth between two cavity mirrors. It will be assumed for the moment that there is no laser medium present. (This condition gives the empty cavity or nonperturbed mode.) The following calculation sequence is used:

Empty Cavity

1. Reflect input wave or waves (a maximum of six waves can be used) from mirror 1. This step corrects the field amplitude for mirror reflectivity and mirror size and corrects the phase of the field for mirror curvature and angular mirror tilt. (For perfectly aligned resonators, mirror tilt is zero.)

2. Propagate one step to $z = \Delta z$ using the following initial propagation algorithm

$$\hat{U}_j^{\,1} = \hat{U}_j^{\,0} + i\,\delta x\left(\hat{U}_{j-1}^{\,o} - 2\hat{U}_j^{\,o} + \hat{U}_{j+1}^{\,o}\right) \tag{8}$$

3. Propagate to mirror 2 (see Fig. 1) using eq. (7) repeatedly for NZ - 1 steps.

4. Reflect from mirror 2. This step corrects the amplitude and phase of the field for the effects of mirror 2.

5. Propagate one step using eq. (8).

6. Propagate to mirror 1 using eq. (7) repeatedly for (NZ - 1) steps.

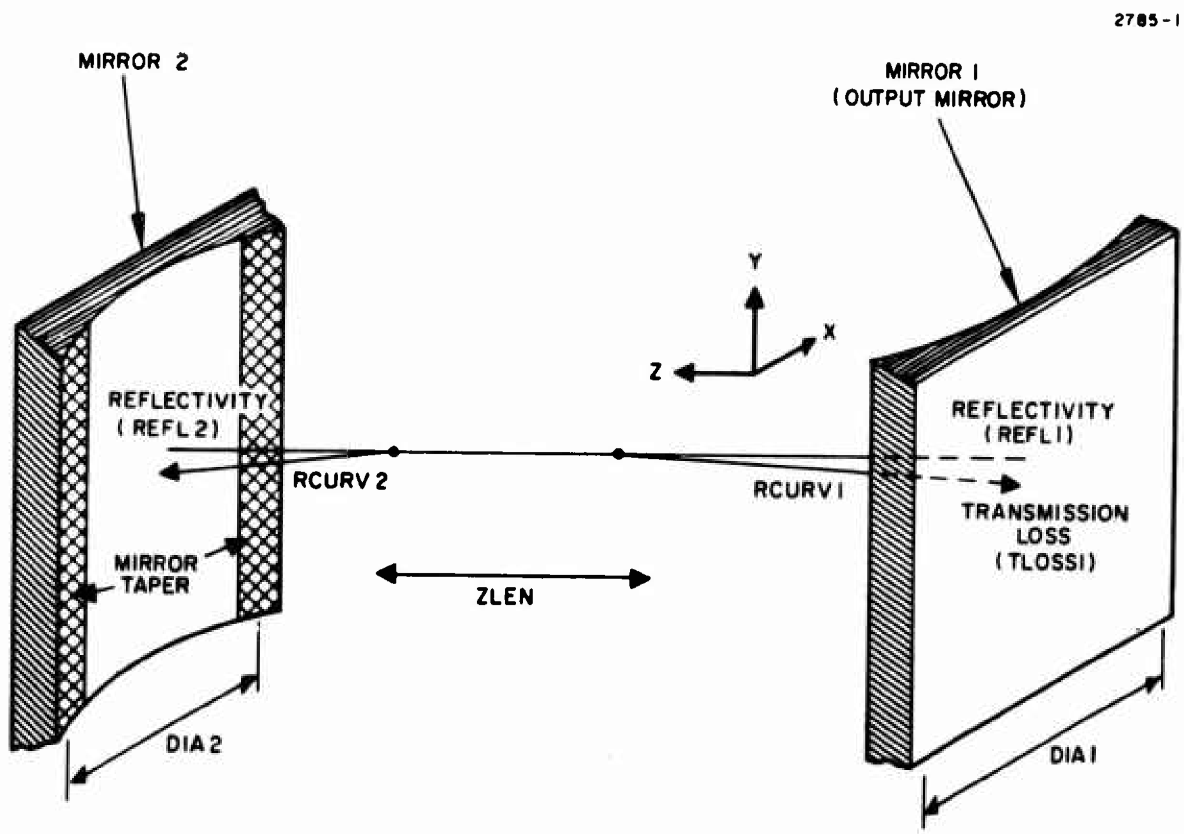


Fig. 1. Resonator geometry for step-by-step computer program.

7. Store real and imaginary terms of $\hat{U}_j$ on a RSTART tape. These values will be used later in a FAR FIELD PROGRAM to compute the far field intensity distribution.

8. Renormalize field amplitude at mirror 1. This step multiplies the field at mirror 1 by a constant so that at this location the area under the distribution curve remains fixed from pass to pass.

9. Repeat steps 1 through 8 for NPASS passes.

By following steps 1 through 9, the many modes that went into defining the input wave will reduce to a single mode, and this mode will be the lowest loss transverse mode of the resonator. This mode is also the lowest loss mode for three-dimensional square mirror geometry and should be interpreted as applying to a cross section through a resonator having square mirrors with spherical surfaces. It should be noted that when a saturable gain medium exists, this equivalence is no longer true.

Figure 2 shows the active laser medium inserted into the calculation procedure. Unlike the FICP, the SSCP is not restricted to low Fresnel number calculations and therefore can treat diffraction in the gain medium. The total gain length of the medium is ZLENMD, where ZLENMD can be equal to or less than ZLEN. The location of the center of the laser medium is located ZMDLOC distance from the mirror 1.

When propagating through the laser medium, the phase and amplitude of the field is adjusted after each propagation step according to eq. (3). Rewriting eq. (3) in terms of the local power gain G_j and the local index of refraction Δn_j, results in the following:

$$\hat{U}(j\Delta x, z + \Delta z) = \hat{U}_o(j\Delta x, z + \Delta z) \exp\left[\left(\frac{G_j}{2} + i K_o \Delta n_j\right) \Delta z\right] \qquad (9)$$

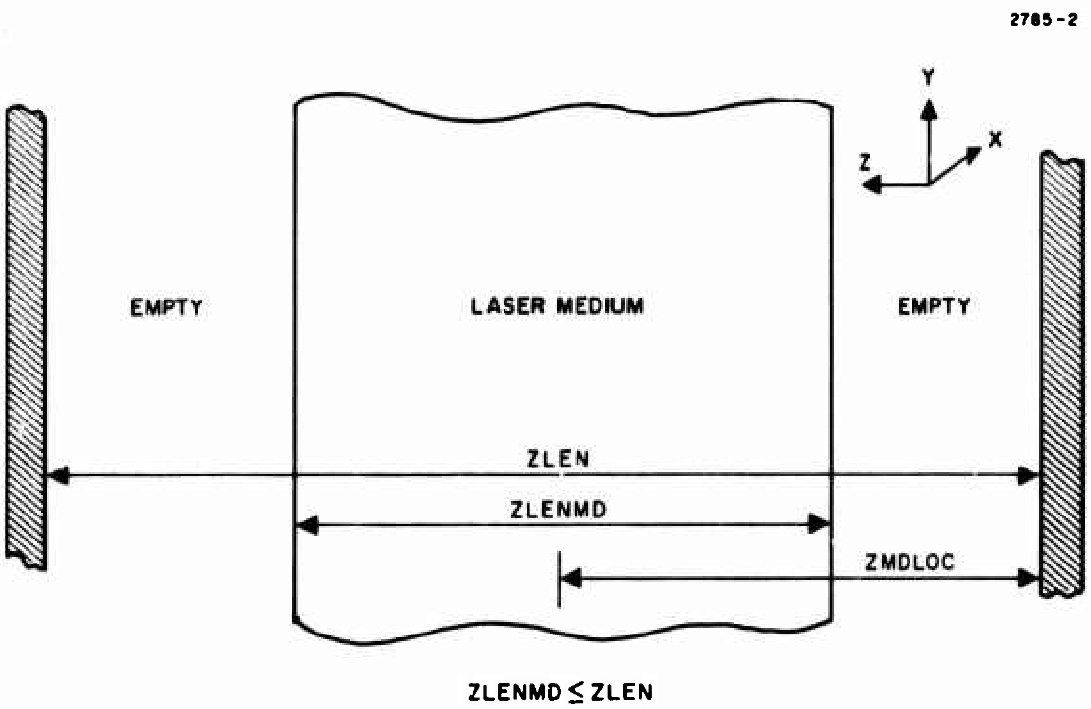


Fig. 2. Resonator geometry with laser medium.

(G_j can be positive or negative depending on whether the medium has gain or loss). Δz is the step size in the gain medium and is equal to ZLEN/NZ and Δn_j is the local refractive index difference. The local power gain G_j can be supplied by a separate gain subroutine such as the Lockheed 2-D, DF-CO_2 (Ref. 3) mixing program or by a built-in gain subroutine GAINA which assumes the gain to be uniform and homogeneously broadened. The latter gain routine is expressed as

$$G_j = \frac{\text{GZERO}}{1 + \dfrac{|\underset{\sim}{U}_T(j\Delta x)|^2}{\text{XIZERO}}} \tag{10}$$

where GZERO is the small-signal gain, XIZERO is the saturation flux density, and $\underset{\sim}{U}_T(j\Delta x)$ is total field amplitude (forward plus backward traveling wave). If the medium is assumed to have uniform density, then $\Delta n_j = 0$. Since this type of gain medium cannot couple laser transitions, GZERO and XIZERO are the same for each propagating wave.

The calculation procedure when the two-dimensional laser medium is included is as follows:

<u>Medium Included:</u>

1. Reflect input wave or waves from mirror 1.
2. Propagate to edge of laser medium using eqs. (7) and (8).
3. Sum present field intensity with field intensity from previous pass traveling in opposite direction (stimulated emission depends on total local intensity).
4. Call gain subroutine. This routine furnishes gain and refractive index values for each field point.
5. Propagate one step in the z direction using eq. (7).
6. Adjust the U_j field points for gain and density variations according to eq. (9).

[3] Chemical Laser Analysis Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RK-CR-73-2, October 1973.

7. Store the intensity ($|U_j|^2$) for each field point. (The total number of times the intensities are stored in the z direction is limited to 21. If the number of propagation steps in the medium exceeds 21, the program automatically skips storing every step in order not to exceed this number.)

8. Repeat steps 5 and 6 for total of IGSKIP times. The parameter IGSKIP requires that IGSKIP propagation steps be made before the gain subroutine is called.

9. Repeat steps 3 through 8 until far side of laser medium is reached.

10. Propagate to mirror 2 using eq. (7).

11. Reflect from mirror 2.

12. Repeat steps 2 through 9.

13. Propagate to mirror 1 using eq. (7).

14. Store amplitude and phase of field points on the RSTART tape. (This data is used in the FAR FIELD PROGRAM to compute the far field intensity distributions.)

15. Repeat steps 1 through 14 for NPASS passes.

Laser power can be coupled out of the laser at either or both ends of the resonator if the beam spills past the edges of the resonator mirrors. The power lost in this way can be determined by taking the beam power before and just after the beam hits a mirror and taking their difference (mirror reflectivity is assumed to be 1). Useful laser power is assumed to occur at mirror 1 and this can be from both spillage and transmission through the mirror (REFL1 $<$ 1.). It is this combined beam that is used to determine the far field.

4. Mirror Edge Tapering

The truncation error terms in eq. (7) contain the following partial derivatives.

$$\text{Truncation Error} = \frac{i}{K_o}\left[\left(\frac{\partial^2 \hat{U}}{\partial z^2}\right)\left(\frac{\Delta z}{\Delta x}\right)^2\right] + \frac{1}{3}\frac{\partial^3 \hat{U}}{\partial z^3}\Delta z^2 - \frac{i}{12K_o}\left[\frac{\partial^4 U}{\partial x^4}\Delta x^2\right] + \cdots \tag{11}$$

Because of the partial derivatives with respect to x, we cannot accurately treat infinitely steep field gradients that occur at sharp mirror edges; therefore, it is necessary to use edge-tapering. In our step-by-step resonator model, the mirror reflectivity at the edge of the mirror is given by the following gaussian function:

$$\text{Mirror Reflectivity} = \text{REFL} \exp\left(-(x - x_o)^2/\text{OMEGA}^2\right), \text{ for } |x| \geq x_o \tag{12}$$

where REFL is the power reflectivity of the mirror, $2x_o$ is the mirror width describing the region of uniform reflectivity, x = o at mirror center, and OMEGA describes the distance of truncation. (When the operator sets DIA1 or DIA2, the program automatically computes x_o such that $x_o = \text{DIA}/2 - \sqrt{0.7 \cdot}\ \text{OMEGA}$. This fixes the effective mirror diameter between the half power points in the taper region.)

C. Step-by-Step Technique (Expanding Coordinates)

The discussion up to this point has outlined the technique for solving for the transverse modes of a laser resonator using the step-by-step propagation technique. As stated in the introduction the step-by-step technique is best suited for large Fresnel number waves. Thus, the step-by-step model should be best suited for studying large Fresnel number resonators. However, this is not the case. Larger Fresnel numbers require increasingly larger numbers of mesh points and therefore more computer time. This is due to the beam curvature

which is introduced into the wave every time the beam bounces off a resonator mirror. For example, in a confocal unstable resonator using a convex and concave mirror (laser output is obtained at the convex mirror), the beam that is reflected from the output mirror has a radius of curvature equal to that of the mirror and thus its effective Fresnel number is much lower than the Fresnel number of the resonator. However, by using an expanding coordinate system, we can remove the dependence of the mirror curvature on the number of mesh points required to accurately propagate the beam. We can propagate the beam back and forth inside the resonator, assuming it is nearly a plane wave, and then by using a suitable coordinate transformation determine the actual beam distribution including phase information.

The SSCP can treat diffraction within the laser medium, but it is limited to studying resonators with Fresnel numbers of approximately 60 or less. However, by going to an expanding coordinate system the Step-by-Step Computer Program (Expanding Coordinate System) SSCP(ECS) does not have an upper limit on the Fresnel number. Because of the importance of large Fresnel numbers in high power laser systems, this user's manual will be mainly devoted to the SSCP(ECS). Features which are explicitly different in the SSCP will be described in Appendix C.

1. Propagation Algorithm (Two-Dimensional)

The propagation algorithm for the expanding coordinate system is similar to the algorithm given in eq. (7) and is expressed as follows.[4]

[4] Chemical Laser Mode Control Program, Semiannual Technical Report, Hughes Research Laboratories, Contract No. DAAH01-73-C-0290, 13 November 1972 through 12 May 1973.

$$\hat{U}_j^{m+1} = \frac{AA}{1+\delta x^2}\left[\hat{U}_j^{m-1} \cdot AA + i\,\delta x\left(\hat{U}_{j+1}^{m} - 2\hat{U}_j^{m-1} \cdot AA + \hat{U}_{j-1}^{m}\right)\right.$$

$$\left. + \delta x^2\left(\hat{U}_{j+1}^{m} - \hat{U}_j^{m-1} \cdot AA + \hat{U}_{j-1}^{m}\right)\right]$$

$$+ \text{Truncation Terms} \qquad (13)$$

where AA is a variable which is a function of z. AA is defined as

$$AA = \left(1 - \frac{\Delta z}{2(z + VR)}\right) \qquad (14)$$

where VR is shown in Fig. 3 as the virtual image source distance with z measured from the mirror as the beam propagates away from it. The virtual source distance VR is a function of the physical parameters of the resonator and is given as[5]:

$$VR1,2 = \left[\frac{\sqrt{1 - (g_1 g_2)^{-1}} - 1 + (g_{1,2})^{-1}}{2 - (g_1)^{-1} - (g_2)^{-1}}\right] \cdot ZLEN \qquad (15)$$

where $g_{1,2}$ are the resonator g parameters defined as

$$g_{1,2} = 1 - \frac{ZLEN}{RCURV1,2} . \qquad (16)$$

Because of the expanding coordinate system δx is no longer a constant since Δx is a function of z. Δx is expressed as follows.

[5]A. E. Siegman, "Unstable Optical Resonators for Laser Applications," Proceedings IEEE, 53, 277-287, March 1965.

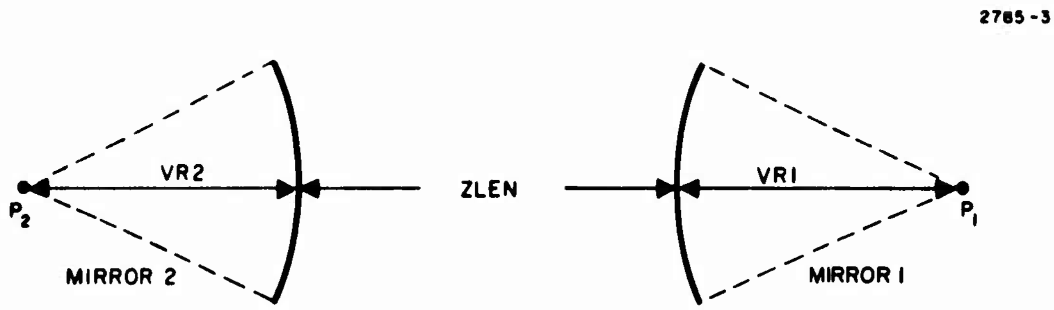


Fig. 3. Geometry showing location of virtual image sources P1 and P2.

$$\Delta x = \text{DXMIR1}\left(1 + \frac{z}{\text{VR1}}\right) \text{ propagating from mirror 1 to mirror 2}$$

$$\Delta x = \text{DXMIR2}\left(1 + \frac{z}{\text{VR2}}\right) \text{ propagating from mirror 2 to mirror 1}$$

(17)

where DXMIR1 and DXMIR2 are the values for Δx at mirror 1 and mirror 2, respectively, and z is again measured from the mirror that the beam is propagating away from.

As a result of the coordinate transformation the SSCP(ECS) differs from the SSCP in that beam expansion or contraction is controlled by the increase or decrease of Δx in eq. (17) and not by the phase curvature placed on the beam upon reflection from a mirror as is the case for the SSCP. In the SSCP(ECS), the transformed mirrors are flat (infinite radius of curvature). The operator, when inputting the mirror radii of curvature, must supply the physical curvatures to the program (these are used to compute the virtual image distances in eq. 15), but the program treats the mirrors as if they were flat when the beam reflects off their surfaces. The divergence or convergence that would be caused by the actual curvature of the mirrors is treated by the coordinate transformation. The operator can supply any mirror curvature to the program as long as all virtual image sources are located outside the resonator. The coordinate transformation cannot treat internal focal points. It should be pointed out that in the SSCP(ECS), the maximum distance traversed in the x-direction depends on the maximum value for Δx.

2. Calculation Procedure

The calculation procedure for the empty cavity configuration is as follows (see Fig. 4).

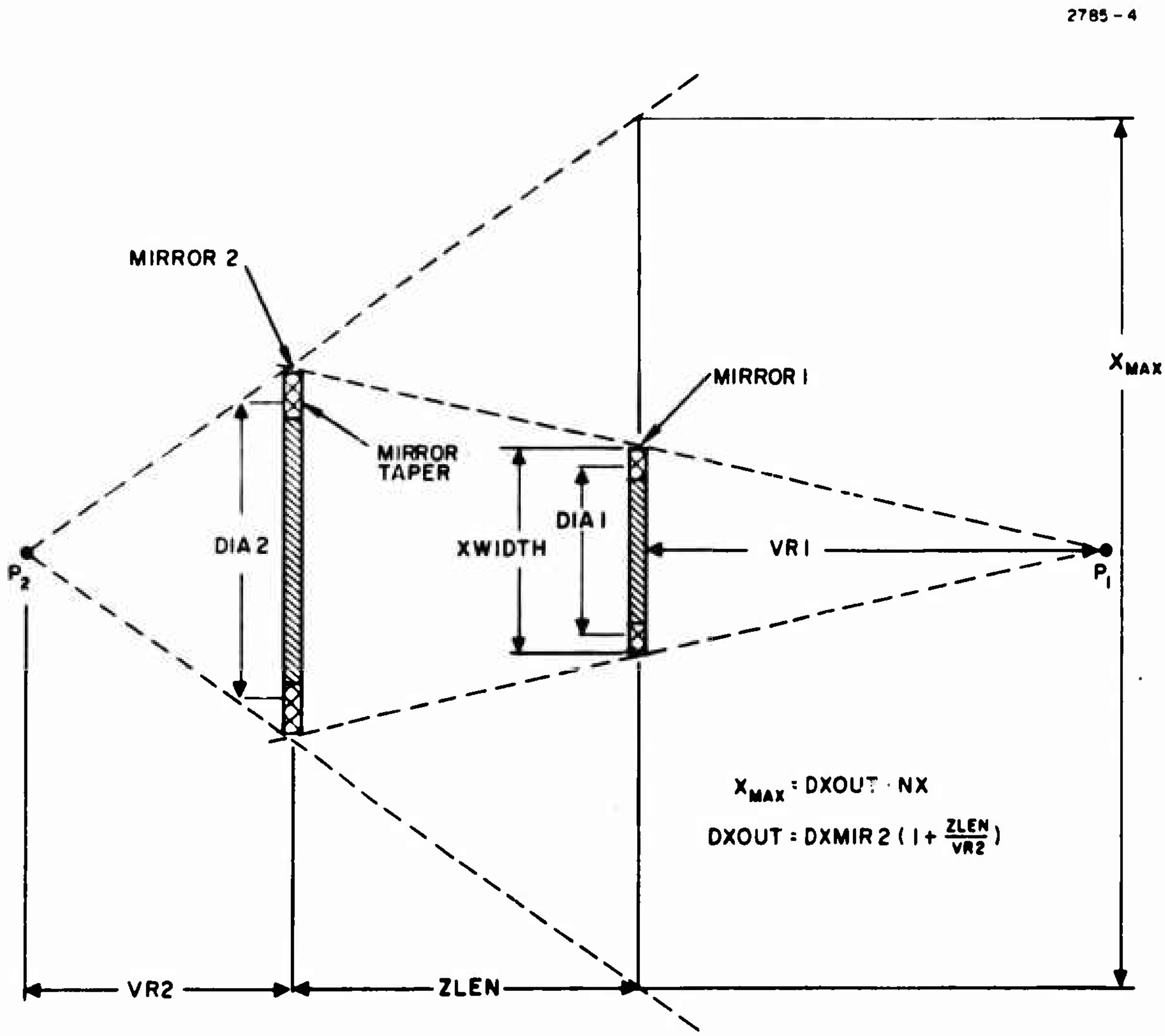


Fig. 4. Resonator geometry for step-by-step propagation with expanding coordinate system.

Empty Cavity

1. Compute VR1 and VR2 and VR2 using eq. (15).

2. Reflect input wave or waves from mirror 1. (Maximum of six waves can be specified.) Mirror 1 and mirror 2 are treated as if they have infinite radius of curvature (flat mirrors), therefore only the spatial properties of the input wave are changed.

3. Compute Δx using eq. (17). (DXMIR1 = XWIDTH/NX, where XWIDTH is an input parameter).

4. Propagate one step to $z = \Delta z$ using eq. (8).

5. Compute Δx using eq. (17).

6. Propagate one step in the z direction using eq. (13).

7. Repeat steps 5 and 6 until mirror 2 is reached.

8. Reflect from mirror 2.

9. Repeat steps 3 through 6 until mirror 1 is reached.

10. Store field points on RSTART tape for use in the FAR FIELD PROGRAM.

11. Renormalize field amplitude. This step multiplies the field at mirror 1 by a constant so that at this location the area under the distribution remains fixed from pass to pass.

12. Reduce the maximum spatial extent of the beam from x_{max} to XWIDTH. This step takes the NX field points which have amplitude and phase information for the beam spaced every DXOUT and replaces every field point with beam information spaced DXMIR1 apart.

13. Repeat steps 2 through 13 for NPASS passes.

For the empty cavity configuration, the operator can determine the total roundtrip losses for the resonator by summing the losses that

occur at each mirror. The loss at mirror 1 is determined by taking the area under the intensity distribution after completing step 11 and subtracting from it the area after step 2. The loss at mirror 2 is the difference in areas after completing steps 7 and 8 [the area after each of the indicated steps is printed as output by both the SSCP and the SSCP(ECS)].

The phase distribution obtained with the expanding coordinate system is normalized to the geometric phase for the output beam. In other words, if there are no perturbations in the resonator, the output phase will be essentially flat (all geometric curvature removed).

To include the laser medium effects in the SSCP(ECS) an additional step, other than the steps outlined for the SSCP, is required to compute the local intensities needed for the gain subroutine. Note in Fig. 4 that propagating from mirror 1 to mirror 2 the total extent of the beam in the x-direction is smaller than for the opposite traveling beam. Since the field points of the two opposite traveling waves do not necessarily coincide, the total local intensity (which is needed for the gain subroutine) must be obtained by interpolation. In addition the matrix containing the local intensities SØTØT and GAIN must be expanded to include field points covering the entire beam of the previous pass when propagating from mirror 1 to mirror 2 at the current z location.

D. Pseudo Three-Dimensional Calculations

In high power laser devices with transverse medium flow, the spatial homogeneity of the near field intensity distribution depends upon the output coupling of the resonator. Since the coupling loss for two- and three-dimensional resonators are not equal [for two-dimensional confocal unstable resonators the loss $(1 - 1/M)$ is considerably less than the three-dimensional loss $(1 - 1/M^2)$], a realistic near-field distribution cannot be obtained with a two-dimensional resonator calculation. Furthermore, three-dimensional calculations are

necessary to determine output power since this quantity also depends upon coupling loss. The SSCP and the SSCP(ECS) contain an option to perform a pseudo-three-dimensional calculation. A description of the calculation technique is given below.

1. Calculation Technique

The three-dimensional cylindrical resonator is divided into two halves about a line running from the top to the bottom of the resonator. The same propagation algorithms used for the two-dimensional resonators can be used if it is assumed that for the right half (downstream half) of the resonator the field amplitude in the resonator is

$$\underset{\sim}{U}_{3d}(r,\phi) = \underset{\sim}{U}_{3d}(r)e^{j\phi} = \underset{\sim}{U}_{2d}(x) , \tag{18}$$

for

$$-\frac{\pi}{2} < \phi \leq \frac{\pi}{2} ,$$

$$0 < x \leq \frac{DIA2}{2}$$

and for the left half (upstream half) of the resonator for field amplitude is

$$\underset{\sim}{U}_{3d}(r,\phi) = \underset{\sim}{U}_{3d}(r)e^{j\phi} = \underset{\sim}{U}_{2d}(x) , \tag{19}$$

for

$$\frac{\pi}{2} < \phi \leq \frac{3\pi}{2} ,$$

and

$$\frac{-DIA2}{2} \leq x \leq 0$$

Thus, for the upstream half of the resonator, the mode distribution is independent of ϕ, and a similar assumption is made about the downstream portion. Next the flux density that the gain medium senses must be adjusted in order to account for the differences in coupling loss. To find this adjustment factor, note that the power contained in a thin strip Δx wide and DIA2 high in a two-dimensional resonator is

$$\Delta p_{2d} = I_{2d} \cdot \text{DIA2} \cdot \Delta x \ , \tag{20}$$

where $I = |U_j|^2$. The power contained in a thin strip Δr wide and covering half a three-dimensional resonator (either the upstream or downstream half) is

$$\Delta p_{3d} = \text{ASR} \cdot I_{3d} \cdot r\Delta r = \text{ASR} \cdot I_{3d} \cdot x\Delta x$$

$$\begin{aligned} \text{ASR} &= \pi \text{ (cylindrical resonator)} \\ \text{ASR} &= 4 \text{ (square resonator)} \\ \text{ASR} &= 0 \text{ (two-dimensional calculation)} \end{aligned} \tag{21}$$

where the center of the resonator mirror is assumed to be located at $x = 0$, and I is the flux density in the laser cavity. Because of the imposed angular requirements (cylindrical resonator) on I_{3d} in the cavity, the three-dimensional cavity flux density can be set equal to the two-dimensional cavity flux density. Thus

$$\Delta p_{3d} = \frac{\text{ASR}}{\text{DIA2}} \cdot x \cdot \Delta p_{2d} \tag{22}$$

However, in order to satisfy eq. (22) the flux density that the medium senses I^p (I^p is the flux density used to calculate the gain which in this case is different from the cavity flux I) must be adjusted as follows

$$I_{3d}^{P} = \frac{ASR}{DIA2} \cdot x \cdot I_{2d} \tag{23}$$

2. Calculation Procedure

The procedure for computing the pseudo-three-dimensional near-field in the presence of a laser medium is similar to the two-dimensional procedure described for the SSCP and the SSCP(ECS). The three-dimensional procedure requires two additional steps. First, since eqs. (7) and (13) conserve the two-dimensional area the field amplitude at each propagation step must be renormalized in order to conserve the three-dimensional area. Each field point is multiplied by the following constant:

$$\text{RATIO} = \text{Renormalization Constant (3-d)}$$

$$= \left(\frac{\sum_i |U_i^m|^2 |x_i - x_c| \Delta x}{\sum_i |U_i^{m+1}|^2 |x_i - x_c| \Delta x} \right)^{1/2} \tag{24}$$

where x_c is the x-dimension for the center of the resonator. The accumulative ratio RCUM3D is the NZ products of RATIO for each propagation step ($\text{RATIO}_1 \cdot \text{RATIO}_2 \cdots \text{RATIO}_{NZ}$). Second, the total local intensities must be adjusted according to eq. (23) before computing the local gain. It should be pointed out that the local intensities are not permanently changed by this adjustment; they retain their original values once the local gain has been computed.

Both programs, the SSCP and the SSCP(ECS) are set up so that when ASR = 0, two-dimensional calculations are made.

E. Program Uses

The Step-by-Step Computer Program (SSCP) and the Step-by-Step Computer Program with Expanding Coordinate System

[SSCP(ECS)], when used to analyze empty cavity resonators, will solve for the amplitude and phase of the lowest loss transverse mode, the total roundtrip loss per pass, the output coupling fraction, the amplitude and phase of the far-field distribution, and the far-field normalized area distribution. This latter distribution gives the total area, or power, under the far-field distribution for a given far-field angle. Both near- and far-field information is provided regardless of the resonator configuration. The resonator may be stable or unstable, perfectly aligned or misaligned as a result of mirror tilt, or have partially transmitting mirrors.

The empty cavity analysis is important because it gives the program user the nonperturbed intensity distributions for any two-dimensional resonator configuration. It also permits the user to determine the effects of mirror misalignment and coupling on the intensity distributions.

With an active medium present, additional information can be obtained from the SSCP and SSCP(ECS). Using the uniformly saturable gain routine contained in the two programs, the user can determine how the intensity distributions are perturbed when saturable gain is present. Furthermore, he can determine if a given small signal gain will cause multimoding in the resonator. For gain routines such as the Lockheed 2-D, DF-CO_2 mixing program,[3] effects from flow, multi-wavelengths, and refractive index gradients can be studied. In addition, of course, parametric studies involving concentration, temperature, and mixing of gas species can be performed in order to determine their effect on the output beam.

F. Limitations

The two-dimensional Step-by-Step Computer Program (SSCP) has three basic limitations. The first limitation is that the analysis is limited to slit or two-dimensional resonators; this restrains the laser medium from varying in the y direction. Therefore, lasers which have

[3] Chemical Laser Analysis Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RF-CR-73-2, October 1973.

free expansion nozzles, shock waves, etc., cannot be accurately analyzed with a two-dimensional analysis. The pseudo-three-dimensional calculation procedure discussed in Subsection D permits the user to eliminate the difference in coupling loss between the two- and three-dimensional resonators; however, the procedure still requires medium uniformity in the y direction.

The second limitation of the SSCP is the size of the Fresnel number of the resonator which can be analyzed. For efficient calculations the number of field points NX should be less than approximately 300. From past experience this requires Fresnel numbers of 60 or less. The Step-by-Step Computer Program with Expanding Coordinate System [SSCP(ECS)] removes this limitation. However, in removing the Fresnel number limit it adds a constraint that no internal focal points can exist inside the resonator (all virtual image sources must be outside the resonator).

The third limitation is the inability to treat infinitely sharp mirror edges. Since the mirror edges must be gradually tapered, the fine structure in the near-field intensity distribution is eliminated. However, the overall structure is not degraded by the tapering of the mirror edges and the net result is an averaging of the fine structure to produce a smooth varying intensity distribution for the transverse modes.

G. Input Data Considerations

Several input variables to the program are not set by the physical dimensions of the laser device being analyzed. A list of these along with a brief description follows:

Variable	Description
NX	Number of field points
NZ	Number of propagation steps between mirrors

Variable	Description
IGSKIP	Number of propagation steps between GAIN calls
AMPINT	Amplitude of input wave (uniform or gaussian ($\sqrt{W}/L$)
WOMEGA	1/e radius of input wave (L)
OMEGA 1, 2	Truncation distance for mirror edges (L)
XWIDTH	Maximum spatial extent of input wave (L)

NX must be chosen such that there are at least two field sample points within the smallest length in the x direction over which the amplitude or phase of the beam changes. The smallest length may be OMEGA or the size of a density variation such as a shock wave. For single mode lasers, NX will be determined primarily by the truncation distance of the mirror edges (see discussion at end of this section).

NZ is determined from the following equation:

$$\Delta z \le \frac{K_o}{2} \cdot \Delta x^2 \tag{25}$$

where

$$\Delta x = \frac{XWIDTH}{NX} \quad \text{and} \quad \Delta z = \frac{ZLEN}{NZ} .$$

Under most conditions, eq. (25) is sufficient to determine Δz; however, if a laser medium is present such that the amplitude or phase of the beam changes by more than 5 or 10%, then Δz must be reduced in order not to exceed this limit.

IGSKIP should be set so that the GAIN subroutine is called whenever the beam amplitude changes by 5 or 10%

The amplitude of the input waves (uniform or gaussian distribution) is set by AMPINT. For empty cavity conditions the field distribution is normalized every pass in order to make the average intensity at mirror 1 equal to 1.0; therefore, AMPINT has no meaning in this

case. For gain filled resonators the distribution is not normalized. Since the final mode distribution must be independent of the input wave, the value for AMPINT is arbitrary. For values less than the saturation levels of the medium, the SSCP and SSCP(ECS) require several passes through the resonator before the medium saturates (gain equals loss). By setting $(\text{AMPINT})^2$ approximately equal to the saturation flux density of the medium, the SSCP and SSCP(ECS) require the fewest number of iterations for a solution.

WOMEGA is the 1/e radius for the input wave or waves. The amplitude distribution for the input is as follows:

$$|U|_{input} = \text{AMPINT} \exp\left(-(x - x_c)^2/\text{WOMEGA}^2\right) . \qquad (26)$$

For uniform distributions, WOMEGA $\rightarrow \infty$.

The truncation distance for the mirror edges is given by OMEGA 1 and OMEGA2. The values for OMEGA should be such that $2 \cdot \text{OMEGA} \lesssim 0.07 \cdot \text{DIA}$. For example, if DIA2 = 10 cm then OMEGA 2 $\lesssim$ 0.35 cm. The purpose of the upper limit on OMEGA is to insure that the taper region does not contribute to a significant portion of the mirror surface. There is an additional consideration that must be made when setting a value for OMEGA. Significant truncation error terms in the propagation algorithm can develop if there are not sufficient sample field points in the taper region; therefore, the operator must be sure that DXMIR $\lesssim$ OMEGA/3. Decreasing OMEGA means that DXMIR must be decreased proportionately. However, DXMIR can only be decreased by increasing NX, which means more computer storage and computation time to analyze the resonator. Therefore the operator must compromise between the sharpness of the mirror edge and computational efficiency.

Since the step-by-step propagation algorithm is a numerical difference method, the first and last field points in the propagation algorithm must always contain zero. Therefore in the SSCP and the

SSCP(ECS), XWIDTH must be large enough to ensure that throughout the entire cavity, significant truncation errors are not introduced by setting the end points to zero (in both programs, the value assigned to the end points are always zero). In the SSCP (where there is no expansion of the coordinate system), XWIDTH must be large enough to include both geometric and diffraction spreading of the beam. For example, on the first pass when the initial beam is reflected from mirror 1 and propagated toward mirror 2, XWIDTH (which is equal to NX $\cdot$ Δx) must be larger than the beam when it arrives at mirror 2 (the beam size at mirror 2 will depend on both the radius of curvature of mirror 1 and diffraction spreading). In the SSCP(ECS), geometric spreading is accounted for by the expanding coordinate system. Therefore, XWIDTH which sets the width of the initial input beam does not have to be made large enough to include geometric spreading, but only large enough to include diffraction. This is the advantage of the expanding coordinate system. When using the SSCP(ECS), XWIDTH usually is slightly larger than DIA1, while in the SSCP, XWIDTH usually is larger than the largest cavity mirror.

II. PROGRAM DESCRIPTION

A. Summary of the SSCP(ECS)

The Step-by-Step Computer Program with Expanding Coordinate System, or SSCP(ECS), is composed of a variety of FORTRAN subroutines and functions. For simplicity, they can be grouped into four divisions based on function: primary, satellite, utility, and input/output routines. The boundaries between divisions are arbitrary; but in general reflect the importance or difficulty of implementation of a subprogram.

Primary routines are generally the longest and most logically complex of a system of routines. In addition, they usually contain the fundamental mathematical concepts and techniques upon which the program was based. The SSCP(ECS) system consists of three such routines.

PR51	Main program, defines input, contains overall logic
P50SBS	Propagates one or more waves through free space
P50MED	Propagates one or more waves one way through a medium

Satellite routines are generally self-contained routines which accomplish some smaller portion (often repetitive) of the overall solution. Four of these routines are incorporated in the SSCP(ECS).

P50GAI	Returns a set of gain values at a particular location in the medium
GAINA	Computes the gain for each element of each wave for some location in the medium
MIRROR	Reflects one or more waveforms from a particular mirror
SETMIR	Sets up a mirror vector

The GAINA routine is described as a satellite routine only because of its mathematical simplicity and its short length. A program such as the Lockheed DF-CO_2 mixing program[3] would obviously be a primary routine when substituted for GAINA.

Utility routines generally have little to do with the calculation that the program system is performing, but accomplish some necessary function instead. The four routines of SSCP(ECS) in this category are:

P50GET	Retrieves one intensity value from the last-pass intensities matrix by a triple linear interpolation
P50INT	Reduces the output wave(s) from fully expanded form to compacted form for start of next pass by linear interpolation
NORM2D	Two-dimensional area conservation (renormalization routine)
RAT3DA	Three-dimensional area conservation routine

Input/output routines are normally special purpose routines designed to manipulate a particular type of input or output in a particular way, and hence are self-explanatory and highly inflexible. Three routines of this class are:

AREA21	Computes and prints the area under a curve
PWROUT	Computes and prints the near field power and power transmitted for one or more waves positioned before the output mirror
RSTART	Restarts a previous run by reading a magnetic tape

The fourth routine in this category, ALLOUT, is in reality a package of routines designed to allow the programmer to describe the type, frequency, and quantity of output he desires while retaining flexibility. Since these routines have nothing to do with the problems

[3] Chemical Laser Analysis Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RK-CR-73-2, October 1973.

which the SSCP(ECS) was designed to handle, their description will be given in Appendix A.

B. Main Program and Key Subprogram Descriptions

1. PR51 (Main Program)

The main program, PR51, defines all input parameters and controls all output either directly (by calling the output package) or indirectly (by supplying an output file code to routines which use the output package). In addition, PR51 controls job flow by initializing certain parameters before each case begins, defining certain vectors (such as the mirror vectors), and defining the manner of execution of the primary routines P50MED and P50SBS.

All important arrays are declared in PR51 and supplied to subprograms through the argument list or by labeled COMMON. This feature permits the user to alter the size of certain arrays as desired to minimize the storage requirement. All arrays dimensioned in PR51 are indexed by one or more of five quantities: (1) the maximum number of propagating points in the x-direction, (2) the maximum number of last-pass intensity values stored in the z-direction, (3) the largest number of propagating waves, (4) the largest number of passes that PR51 can handle, and (5) the largest number of gain values that PR51 can handle. These five values are assigned to variables NXDIM, NZDIM, NWDIM, NPDIM, and NGDIM, respectively, and appear in a DATA statement at sequence number 1820. Table I describes the relationship between each subscript of each array and the approximate quantity involved. The abbreviations used in the table are

$X \equiv \mathrm{NXDIM}$

$Z \equiv \mathrm{NZDIM}$

$W \equiv \mathrm{NWDIM}$

$P \equiv \mathrm{NPDIM}$

$G \equiv \mathrm{NGDIM}$

TABLE 1. PR51 ARRAY SUBSCRIPT REFERENCES

Array Name	Array Type	Subscript Reference No.		
		1	2	3
T	Complex	X	W	-
U	Complex	X	W	-
V	Complex	X	-	-
XMIR1	Complex	X	-	-
XMIR2	Complex	X	-	-
GAIN	Complex	G	W	-
SO	Real	X	Z	W
SONEW	Real	X	W	-
SOTOT	Real	G	W	-
XLAMDA	Real	W	-	-
XKZERO	Real	W	-	-
AMPINT	Real	W	-	-
INFOUT	Real	P	-	-
WOMEGA	Real	W	-	-
X	Real	X	-	-
OUT1	Real	X	-	-
OUT2	Real	X	-	-
OUT3	Real	X	-	-
OUT4	Real	X	-	-
OUT5	Real	X	-	-
OUT6	Real	X	-	-
OUT7	Real	X	-	-

T1100

Should the user need to change one or more of the dimensions of PR51, he should first identify which arrays are affected (by Table I) and then change each array declaration in PR51 to reflect the changed dimension. Last, he should change the appropriate value in the DATA statement at sequence number 1820 so that all subprograms will automatically handle the change.

2. Selected Subprogram Descriptions

Flowcharts and listings are provided in Appendix E for each primary routine and the more complex satellite and utility routines. Other routines, including the output package (GPOP), have only listings. Documentation describing the purpose of each routine and the nature of the arguments supplied are provided in the listings themselves with the exception of three GPOP routines. The description of GPOP usage appears in Appendix A. The information provided by the listings (and, if present, the flowchart) is generally sufficient to adequately describe the subprogram. However, three routines warrant further mention.

P50GAI

The critical feature of P50GAI is the storage and retrieval of the last-pass intensities prior to the call to the gain routine. Since a major portion of dimensioned storage lies in the SO (last-pass intensity) matrix, a facility exists by which the user can avoid storing intensities at every medium propagation step. When retrieving intensity values from the matrix, therefore, a linear interpolation procedure is used to derive an approximate intensity value for each field point. As the propagation proceeds along the z-direction, current intensity values are stored in place of last-pass intensities which are no longer needed so that the wave re-entering the medium during the next P50GAI call will contain new values. The SO index in the z-direction increments when propagating toward the back mirror, and decrements when propagating toward the output mirror.

SETMIR

The mirror setup routine, SETMIR, computes three components for each location of the mirror matrix. The first, reflectivity, is supplied directly to the routine as an input parameter but may be locally adjusted by SETMIR to accommodate edge tapering (see Section I. B. 4). The second component, mirror curvature, is defined as

$$CURV_i = \exp\left[-jK_o(x_i - x_c)^2/RCURV\right] , \qquad i = 1, 2, \cdots, NX$$

where

x_c is the x-value at the mirror center

RCURV is the mirror radius of curvature.

The third component, mirror tilt, is defined as

$$TILT_i = e^{j[2K_o\beta(x_i - x_c)]} , \qquad i = 1, 2, \cdots, NX$$

where

β = mirror tilt angle (radians).

GAINA

The gain routine returns an array defining the power gain and refractive index variation of the medium for each wave and each field point at a desired z-location. The gain matrix is complex, with the real part containing the local power gain, g_j, and the imaginary part containing the refractive index variation, $\Delta\eta_j K_o$. The GAINA routine supplied with the SSCP and SSCP(ECS) only returns a power gain.

C. Input Description

PR51 is the only routine in the SSCP(ECS) package requiring input to be prepared by the user. All such input is entered on data cards by the FORTRAN NAMELIST convention, with which the reader is assumed to be familiar. (A complete description can be found in the FORTRAN reference manual.) In general, a NAMELIST data record consists of a "$" in column 2 of the data card followed immediately by the particular NAMELIST name for this record, followed by one or more blanks or a comma, followed by the list of variables and corresponding values (in the form of assignment statements separated by commas), and finally terminated by a "$".

Two NAMELIST group names are used by PR51, the first, CASENO, used to define the number of cases to be analyzed during the run, and the remaining one used for each case to describe all run conditions, geometry, and constraints. The data deck for a run will always have as its first NAMELIST record a card of the form

$CASENO NCASES = 5$

to describe the number of cases to be analyzed (here set to "5" for illustration). Following this card will be NCASES groups of cards, each group having a first card starting "$INPUT..." and a last card ending with a "$" following the last data value defined.

The parameters which must be defined in the case description block named "INPUT" are:

(Title)

CASE	Real number in format XXX.XX to be displayed for titling purposes on output as case number

(Run option descriptions)

NPASS	The number of passes which the starting wave is to be propagated (no upper limit)
IFILE	The FORTRAN file code on which all normal output will appear (normally = 6)
IRCODE	FORTRAN file code for restarting a previous run, if >0 (must match the file code assigned to a magnetic tape on a system control card)
IRTAG	Pass number from which restart information is desired from file code IRCODE, if IRCODE > 0
IROUT	FORTRAN file code for generating a tape for later restart or far field analysis, if >0 (must match the file code assigned to a magnetic tape on a system control card)

(Cavity description)

NX	Number of propagating field points (see Section I-G and II-B-1)
XWIDTH	Minimum spatial extent in x of the beam (see Fig. 4), L*
NZ	Number of propagation steps to be taken between mirrors (see Section I-G and II-B-1)
ZLEN	Distance between mirrors, L
XCENTR	Relative location along x of mirror axis centerline, L
ASR	Pseudo-three-dimensional parameter (see Section I-D-1)

*Unit of length is arbitrary but must be consistent for a data case.

(Medium description)

ZMDLOC	Location of the center of the medium relative to the output mirror, L (see Fig. 2)
ZLENMD	Length of the medium, L (see Fig. 2)

(Gain routine description)

IGSKIP	Skip parameter for call to GAINA, where IGSKIP = 3 would call the gain routine every third propagation step (see Section I-G)
GZERO	g_0, the small signal gain used by GAINA, L^{-1}
XIZERO	I_0, the saturation flux density used by GAINA, watts/L^2

(Input wave description)

NWAVES	The number of propagating waves
XLAMDA	λ, or wavelength for each wave; array of NWAVES, L
AMPINT	Initial amplitude for each wave (see Section I-G); array of NWAVES, $(\text{watts})^{1/2}/L$
WOMEGA	ω for each gaussian input wave, if >0 (see Section I-G); array of NWAVES, L

(Mirror descriptions)

DIA1	Diameter of output mirror, L
DIA2	Diameter of back mirror, L
REFL1	Power reflectivity of output mirror*
REFL2	Power reflectivity of back mirror*
RCURV1	Radius of curvature of output mirror, L
RCURV2	Radius of curvature of back mirror, L

*Fraction with values between 0 and 1.

OMEGA1	1/e truncation distance for output mirror edges (see Section I-G), L
OMEGA2	1/e truncation distance for back mirror edges (see Section I-G), L
TILT1	Tilt angle of output mirror, radians
TILT2	Tilt angle of back mirror, radians
TLOSS1	Power loss of output mirror*

(Output option selection)

INFOUT	Near field print options (a "zero" stored in the i^{th} location of this vector will suppress the output for the matching pass number; a "one" will produce the normal output); array of NPASS

D. Restart Facility

PR51 controls the generation of a restart tape if a certain option is supplied, while RSTART controls the search of a restart tape to find and read a desired waveform if two other parameters are supplied. The user will normally not be concerned with the format of the data on the tape since the program handles the information solely on the basis of three input variables during case definition (IRCODE, IRTAG, and IROUT). Should it be necessary to know the format of the data on the restart tape, the following information should be sufficient.

The information on the restart tape is written by FORTRAN unformatted (binary) WRITE statements. The first record consists of five words regarded as titling information only. The second record consists of 20 words used for describing the quantity of information to be read from the tape. The first word of the integer array is NX, the second is NZ, and the third is IWAVE, where these variables represent the number of propagating field points in the x-direction, the number of SO matrix locations used for storage in the z-dimension,

*Fraction with values between 0 and 1.

and the number of propagating waves (NWAVES in data input section), respectively.

The remaining logical records on the tape occur in groups of three, each group representing the results of a different round-trip pass.

Record	Information Contained
1	The pass number for this set of information. (This number is searched for if a restart is requested.)
2	The near-field pattern for each propagating wave, written and read by ([U(I, J), I=1, NX], J=1, IWAVE)
3	The last-pass intensities matrix, so that propagation can be continued; written and read as [([SO(I, J, K), I=1, NX], J=1, NZ), K=1, IWAVE)]

Groups of three logical records are read at a time in the event of a restart until the pass number read from the tape matches the restart number supplied by input variable IRTAG.

E. Gain Routine Replacement

GAINA, the gain routine provided with SSCP(ECS) is designed to be replaced with a more sophisticated routine whenever desired. A replacement of this nature will be simplest if the new routine uses the same name and calling arguments as does the present GAINA routine. If additional arguments (such as g_o and I_o in GAINA) are required, provision for their initialization can be made by including a labeled COMMON block in both PR51 and the gain subroutine and initializing the parameters by a READ statement, an initialization subroutine, or by a BLOCK DATA subprogram. Modification of the argument list required for the gain routine is not recommended since at least the P50GAI routine would have to be changed, and possibly P50MED, to assure that the arguments are passed successfully to the gain routine.

III. MACHINE UTILIZATION

The SSCP(ECS) package is written in FORTRAN IV. The program was originally written for a GE635 computer operating under the GECOS III operating system, though this manual reflects changes made allowing the program to run on a CDC 6600 computer operating with the SCOPE monitor (Version 3.4). This requires about 34K (decimal) or 103K (octal) words of memory, of which

$$NXDIM[(NZDIM + 7)NWDIM + 12] + NWDIM(3 \cdot NGDIM + 6)$$
$$+ NPDIM + NZDIM$$

resides in dimensioned arrays in the main program. For the current dimensioning parameters

$$NXDIM = 101$$

$$NZDIM = 21$$

$$NWDIM = 2$$

$$NPDIM = 101$$

$$NGDIM = 1001$$

the total storage required for dimensioned variable storage is 13,000 words (decimal) or 31,300 words (octal).

Processor time depends on too many parameters and option settings to be accurately estimated, but the longest case analyzed so far consumed about two minutes on the CDC 6600 and about 15 minutes on the GE635.

REFERENCES

1. Two-Dimensional Fresnel Integral Computer Program, User's Manual, Hughes Research Laboratories, Contract No. DAAH01-73-C-0298, May 1973.

2. R. D. Richtmyer and K. W. Morton, Difference Methods for Initial-Value Problems, Interscience Publishers, second edition, 1967.

3. Chemical Laser Analyses Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RK-CR-73-2, October 1973.

4. Chemical Laser Mode Control Program, Semiannual Technical Report, Hughes Research Laboratories, Contract No. DAAH01-73-C-0290, 13 November 1972 through 12 May 1973.

5. A. E. Siegman, "Unstable Optical Resonators for Laser Applications," Proceedings IEEE, Vol 53, pp. 277-287, March 1965.

APPENDIX A

GENERAL PURPOSE OUTPUT PACKAGE (GPOP) DESCRIPTION

The GPOP package was written to eliminate the need for specialized output routines (and to eliminate the inevitable errors incurred during their development) while still retaining enough flexibility that output could be tailored to a program's needs. The routine is able to handle real or complex vectors and perform various normalization operations on the data to be displayed. Tables and/or printer plots can be specified for any vector as can a skip parameter in case the data need not be tabled in their entirety. Pages are titled and data are headed by the appropriate user-supplied column heading. Up to seven vectors of information can be handled at once. Since all such output is fully specified by providing the appropriate information in a FORTRAN subroutine CALL statement, the possibility of user error is virtually eliminated.

<u>Usage</u>

CALL ALLOUT (IFILE, NPTS, ISKIP, NMAT, NCHAR, LABEL,

$ITYPE_1, IOPT_1, NCHAR_1, LBL_1, AMAT_1, DUMMY_1,$

.

.

.

$ITYPE_n, IOPT_n, NCHAR_n, LBL_n, AMAT_n, DUMMY_n)$

where $n \equiv NMAT$ and $1 \le n \le 7$.

Description of Parameters

IFILE	Output file code
NPTS	Number of points in each user vector
ISKIP	Skip parameter for vectors (i.e., use every ISKIPth location)
NMAT	Number of vectors supplied to ALLOUT, ≤ 7
NCHAR	Number of characters in title
LABEL	Title (either an array or a Hollerith literal)

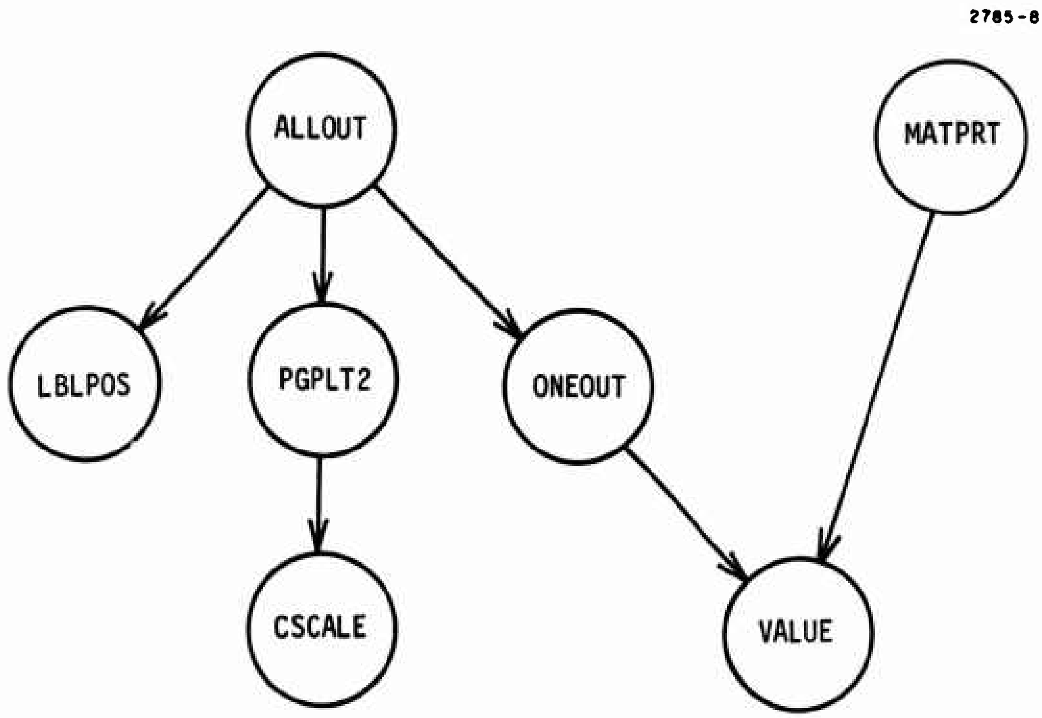
for each vector:

$ITYPE_i$	Matrix type (1 = real, 2 = complex) for ith vector
$IOPT_i$	Output option (described below) for ith vector
$NCHAR_i$	Number of characters in label for ith vector
LBL_i	Label for ith vector (array or Hollerith literal)
$AMAT_i$	Name of user matrix to be displayed
$DUMMY_i$	Dummy vector supplied by user (dimensioned at least NPTS)

The $IOPT_i$ option is a seven-digit integer which completely describes the sort of output to be produced from the corresponding vector. Each digit has a specific meaning. For the description below, assume that the integer's digits are numbered from right to left (i.e., 7654321), and that numbers shorter than seven digits will have zeroes assumed for the leftmost digits.

Digit Number	Options	
1	Value type to be taken from vector	
	0	number is assumed real
	1	real part of complex number
	2	imaginary part of complex number
	3	magnitude of complex number
	4	intensity of complex number
	5	phase (radians) of complex number
	6	phase (degrees) of complex number
2	Option for tabular output	
	0	no tabular output for this vector
	1	produce tabular output for this vector
3	Option for printer plot	
	0	no plot for this vector
	1	plot vector versus $AMAT_1$, full page scaling
	2	plot vector versus $AMAT_1$, plot scaled for "convenient" axis increments

Digit Number	Options	
4	Not currently used	
5	Option for normalization type	
	0	no normalization
	1	vector normalized to one by division
	2	vector normalized to zero by subtraction
6	Option for position of normalization	
	0	no normalization
	1	center point is normalized to zero or one
	2	highest value point normalized to zero or one
	3	lowest value point normalized to zero or one
7	Option for normalized area plot	
	0	produce vector itself
	1	use vector to produce normalized area plot



ALLOUT	main routine of the GPOP set; produces a complete set of listings and/or plots when referenced by a CALL statement
ONEOUT	prepares one vector to be listed and/or plotted; called once for every vector supplied to ALLOUT
VALUE	computes the value for one location in the vector to be listed and/or plotted; called for each location of every vector handled by ONEOUT
LBLPOS	positions alphanumeric column heading above each vector to be listed
PGPLT2	produces line printer plot
CSCALE	scales axes for PGPLT2

Fig. A1. GPOP subprogram references.

APPENDIX B

FAR FIELD PROGRAM DESCRIPTION

I. SYSTEM DESCRIPTION

A. Introduction

The purpose of the FAR FIELD PROGRAM (FFP) is to determine the far-field intensity distribution of the laser output beam, the total far-field power, and the incoherent average of the near- and far-field intensity distributions (averaging is only necessary if the laser is operating multimode).

The method used to determine the far-field intensity distribution is to take the near-field distribution that is transmitted by the output mirror and multiply each field point by a phase correction factor exp $(i\, K_o(x - x_c)^2/(RCURV)$, where x_c is located at mirror center. This correction factor acts as if the output beam is reflected from a spherical mirror having a radius of curvature RCURV. This is referred to as a far-field mirror. The far field is by definition located in the focal plane of a spherical mirror, therefore propagating the beam reflected from the far-field mirror a distance ZLENFF = RCURV/2, the far-field intensity distribution is obtained for the output laser beam.

Incoherent averaging is used whenever the output beam is multimode or, in other words, whenever the transverse mode does not stabilize but continues to change from pass to pass. The averaging is performed by adding the intensities, at each field point, to each successive pass through the resonator and dividing by the number of passes averaged. For multimode lasers, both the averaged near- and far-field intensity distributions will converge to a stable solution after sufficient averaging.

B. Calculation Procedure (Empty Cavity)

For two-dimensional (ASR = 0) far-field distributions the computational procedure is straightforward. The near field amplitude and phase for the empty cavity is obtained from the RSTART tape. This distribution is multiplied by mirror 1 (output mirror) and the resulting distribution (e.g., the portion of the beam that spills past the edges of the mirror plus the portion transmitted by mirror 1) multiplied by the far-field mirror. Finally the beam is propagated to the focal plane of the mirror by a two-dimensional Fresnel integral (see Ref. 1 for a description of the Fresnel Integral). The user must choose RCURV so that the spatial extent of the far field distribution is similar to the spatial extent of the near field. For example, if RCURV is too small, the number of sample points containing significant information will be a small percentage of the total number of sample points NX.

When ASR ≠ 0 or in other words when pseudo three-dimensional calculations are being made, the far-field calculation procedure is similar to that described above except the two-dimensional Fresnel integral must be replaced with a three-dimensional Fresnel integral. The following propagation algorithm is used to find the far-field distribution (in a transverse plane cutting through the focal point) for a cylindrical near-field distribution in Section I-D.

$$U(x) = -\frac{iK_o}{2}\sum_{j=1}^{Nx/2} |x| e^{iK_o\frac{\left(x^2+(j\Delta x)^2\right)}{RCURV}} \left(J_o\left(\frac{K_o xj\Delta x}{ZLENFF}\right) - i\, H_o\left(\frac{K_o xj\Delta x}{ZLENFF}\right)\right)$$

$$\cdot\, U(j\Delta X)\Delta X - \frac{iK_o}{2}\sum_{j=Nx/2}^{Nx} |x| e^{iK_o\frac{\left(x^2+(j\Delta x)^2\right)}{RCURV}}$$

$$\cdot \left(J_o\left(\frac{K_o xj\Delta x}{ZLENFF}\right) + i\, H_o\left(\frac{K_o xj\Delta x}{ZLENFF}\right)\right)U(j\Delta x)\Delta x\,, \qquad (1)$$

for $x \le 0$,

where x is measured in the far field plane with the center located at $x = 0$, $U(j\Delta x)$ is the output beam (includes both real and imaginary terms), and H_o is the Struve function. For $x \geq 0$, the far field distribution is found by changing the sign in front of the Struve functions.

C. Calculation Procedure (Laser Medium Included)

Since the step-by-step propagation algorithm requires that mirror edges be tapered, the phase distribution for the near field transverse mode will change significantly for small changes in x in the region of the taper (note that this rapid phase change occurs in the taper region). This change is seen as an increase in the phase curvature as $|x|$ increases. In empty cavity resonators, the amplitude of the beam in the taper region falls rapidly and therefore the small amplitude combined with a rapidly changing phase does not significantly distort the far-field distribution. However, in transverse flow lasers where the upstream portion of the resonator can have considerably higher unsaturated gain (especially in the taper region), the amplitude of the beam in the taper region may no longer be insignificant and therefore there could be significant distortion in the far field due to the taper region. To correct for this effect which is introduced because of the necessity to taper the mirror edges, there is an option in the FAR FIELD PROGRAM to take the phase of the output beam from the gain filled resonator and subtract from it the phase of the empty cavity output beam (obtained from empty cavity RSTART tape). This removes the phase curvature due to the taper region, but does not affect any phase distortion introduced by the medium.

The use of the phase subtraction is an operator option. Experience has shown that the phase curvature in the taper region for the SSCP(ECS) is considerably smaller than for the SSCP and therefore phase subtraction has not been needed when the SSCP(ECS) was used. To better understand the phase subtraction, refer to Fig. B1. Figure B1(a) shows a typical near-field phase distribution for an empty

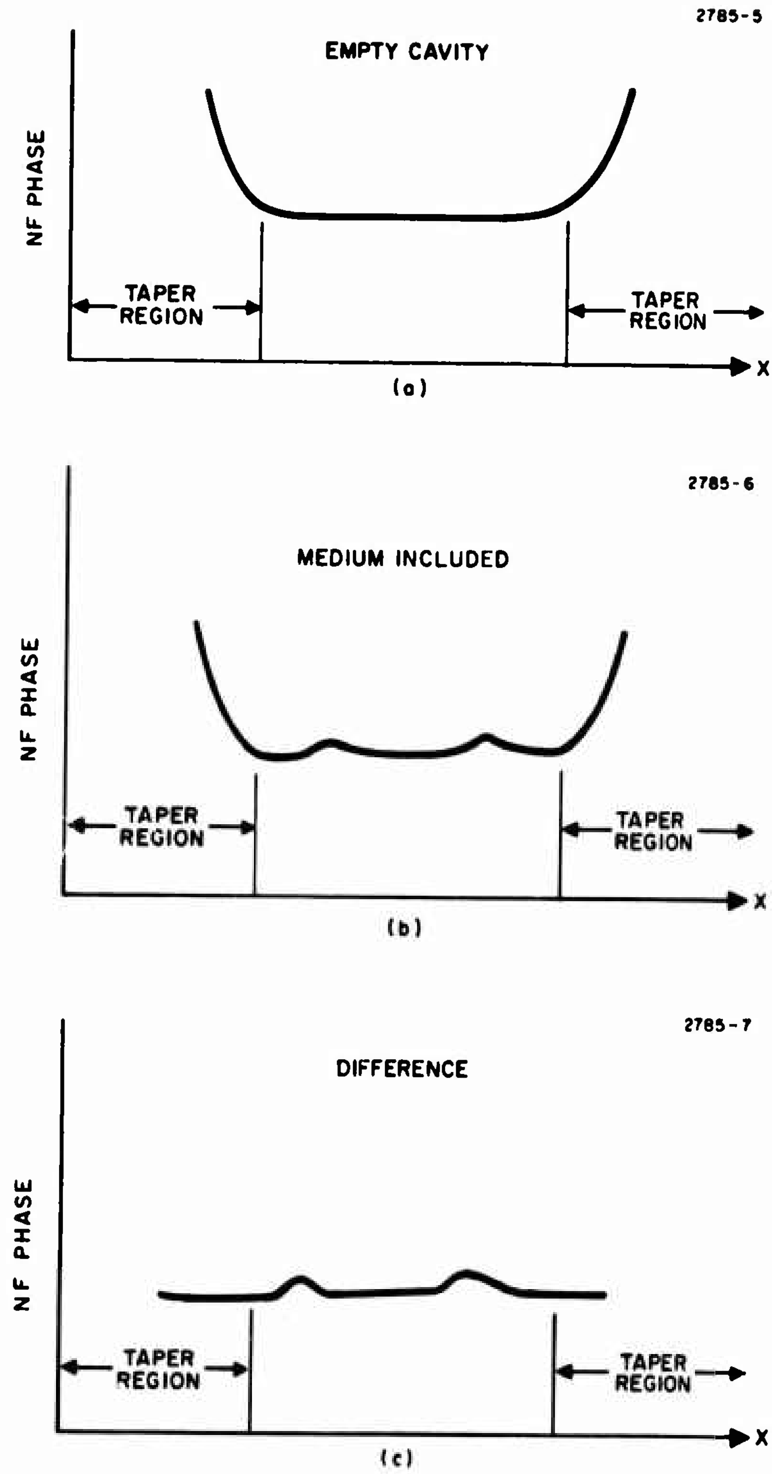


Fig. B1. Example of phase subtraction when computing far field intensity distributions in the far field program.

confocal unstable resonator. The phase is essentially flat in the center of the resonator and increases rapidly in the taper region. The phase distribution for the medium filled resonator looks essentially the same as the empty cavity distribution except for some distortion near the center. The difference in the two distributions is shown in Fig. B1(c) and is essentially flat everywhere except for the distortion caused by the medium. The far field distribution for the last two phase distributions (assuming some amplitude distribution) will be the same if the amplitude is small in the taper region. However, if the amplitude is not small in the taper region, the far-field distribution for the second phase distribution will appear distorted. Thus by using the third phase distribution, the rapidly varying phase in the taper region is eliminated.

II. PROGRAM DESCRIPTION

A. Summary of the FFP

The Far Field Program (FFP) is composed of primary, satellite, and input/output routines of the sort described earlier. The two primary routines are

FFLD	Main program, defines input, contains overall logic
FFLDAV	Propagates one or more waves to the far field; controls averaging; controls output of far field and averaging information

Four satellite routines are contained in the FFP.

PMAT30	Sets up a Fresnel integral vector for two-dimensional propagation to the far field
SETM01	Sets up the far field mirror vector
FFPRP2	Propagates a wave to the far field by three-dimensional propagation
STRUVE	Computes the Struve function by Taylor series approximation

The three input/output routines, RSTART, AREA21, and ALLOUT have been discussed in Section II-A of the SSCP(ECS) part of this manual and will not be further discussed here.

Four of the routines deserve further mention at this point.

FFLD

FFLD, the main program, controls the definition of the input near field wave prior to calling the far field/averaging routine (FFLDAV). The procedure in constructing the near field wave is to define both a "primary" and a "secondary" wave, where the latter may not be supplied for certain cases. When phase subtraction of the empty cavity waveform is desired, the secondary wave is restored

from the specified magnetic tape and the phase correction terms computed. As each primary wave is restored (from a different tape), it is phase-corrected by the secondary wave (if it has been supplied) to yield the desired near field waveform.

There is no functional difference between restart tapes generated by the SSCP and those generated by the SSCP(ECS) – both are fully compatible with the tape requirements of the FFP package. The difference has, in the past, been that an SSCP tape will also require the empty cavity secondary tape for phase subtraction while the SSCP(ECS) primary tape exhibits a sufficiently flat phase profile to not warrant the empty cavity tape. The latter situation is a significant advantage since the number of tapes should be minimized for faster job turnaround.

SETM01

The mirror setup routine, SETM01, computes three components for each location of the mirror matrix. The first is the transmission distribution. The distribution takes into account the size of the output mirror DIA1, the output mirror reflectivity REFL which is constant over the mirror surface, and the transmission loss TLOSS1 of the output mirror. This distribution when multiplied by the near field distribution taken from the RSTART tape, gives the field distribution incident on the far-field mirror. The second component, curvature, is defined as

$$CURV_i = \exp\left[-jK_o(x_i - x_c)^2/RCURV\right], \qquad i = 1, 2, \cdots, NX$$

The third component, mirror tilt, is defined as

$$TILT_i = e^{j\left[2K_o\beta(x_i - x_c)\right]}, \qquad i = 1, 2, \cdots, NX$$

where

$\beta \equiv$ mirror tilt angle

$x_c \equiv$ x at the mirror center

RCURV $\equiv$ radius of curvature of the far-field mirror

PMAT30

PMAT30 generates the Fresnel Integral matrix by which diffraction propagation is performed. To simplify computation, the matrix is symmetrical around the (2·NX-1) point. In general, the i^{th} value of the matrix is defined as

$$\Delta x \cdot \sqrt{\frac{1-j}{2L\lambda}}\, e^{jK_o[(i-1)\Delta x]^2/2L}$$

where

L ≡ ZLENFF, or far-field propagation distance

though the procedure in PMAT30 performs this computation in a different form than that shown.

FFLDAV

The concept of averaging is included in the FFLDAV routine along with the far-field propagation (which is straightforward). Averaging can be used independently on either the near-field or the far-field intensity distribution or both, and consists of a numerical average at each point of all the values of the intensity distribution over some set of passes.

B. Input Description

FFLD is the only routine in the FFP package requiring input to be prepared by the user. All such input is entered on data cards by the FORTRAN NAMELIST convention, with which the reader is assumed to be familiar. (A complete description can be found in the FORTRAN Reference Manual.) In general, a NAMELIST data record consists of a "$" in column 2 of the data card followed immediately by the particular NAMELIST name for this record, followed by one or more blanks or a comma, followed by the list of variables and corresponding values (in the form of assignment statements separated by commas), and finally terminated by a "$."

Two NAMELIST group names are used by FFLD, the first, CASENO, used to define the number of cases to be analyzed during the run, and the remaining one used for each case to describe all run conditions, geometry, and constraints. The data deck for a run will always have as its first NAMELIST record a card of the form

$CASENO NCASES = 5$

to describe the number of cases to be analyzed (here set to "5" for illustration).

Following this card will be NCASES groups of cards, each group having a first card starting "$INITL. . ." and a last card ending with a "$" following the last data value defined.

The parameters which must be defined in the case description block named "INITL" are:

ASR	Pseudo-three-dimensional parameter (see Section I-B in this appendix)
IPSTRT	Pass number at which to initially restore the primary wave (≥0)
IPFIN	Last desired pass for which a near field wave is to be constructed (≤NPASS of run generating tape)
ISTAG	The pass number of the wave to be designated the secondary wave (≤NPASS of run generating tape)
IPCODE	Primary wave's file code, >0
ISCODE	Secondary wave's file code, if >0
IFILE	The FORTRAN file code on which all normal output will appear (normally = 6), >0
NWAVES	The number of waves to be taken from tape (≤NWDIM in FFLD)

ZLENFF	The far field propagation distance (normally half the far field radius of curvature)
RCURV	The far field radius of curvature (see Section I-B in this appendix)
XK0	The wave number ($2\pi/\lambda$) for each wave; array of NWAVES, L^{-1}
DX	The spacing between field points
NX	The number of field points (≤NXDIM in FFLD)
TLOSS	The power loss of the output mirror*
REFL	The power reflectivity of the output mirror*
BETA	Tilt angle of far field mirror, radians
DIA1	Diameter of output mirror, L**
DIA2	Diameter of back mirror, L
VR2	Virtual source distance for the back mirror; (set to 1.E30 if SSCP(ECS) not used)
ZLEN	Distance between cavity mirrors, L
INFOUT	Near field print options; array of IPFIN (≤101) 0 stored in the i^{th} location of this vector will suppress the near field output for the matching primary pass number 1 stored in the i^{th} location of this vector will produce full near field output for the matching primary pass number

*Decimal percent between 0 and 1

**Units are arbitrary but must be consistent for a case.

IFFOPT — Far field propagation and near/far field averaging switch, where the i^{th} location in IFFOPT controls the matching primary pass number

- 0 Do not propagate to FF; do not average NF or FF
- 1 Propagate to FF; do not average NF or FF
- 2 Do not propagate to FF; average NF only
- 3 Propagate to FF; average NF only
- 4 Propagate to FF; average FF only
- 5 Propagate to FF; average both NF and FF

IFFOUT — Far field averaging output options, where the i^{th} location in IFFOUT controls the output for the matching primary pass number

- 0 Print neither set of results
- 1 Print FF results only
- 2 Print averaging results only
- 3 Print both FF and averaging results

C. Flowcharts and Listings

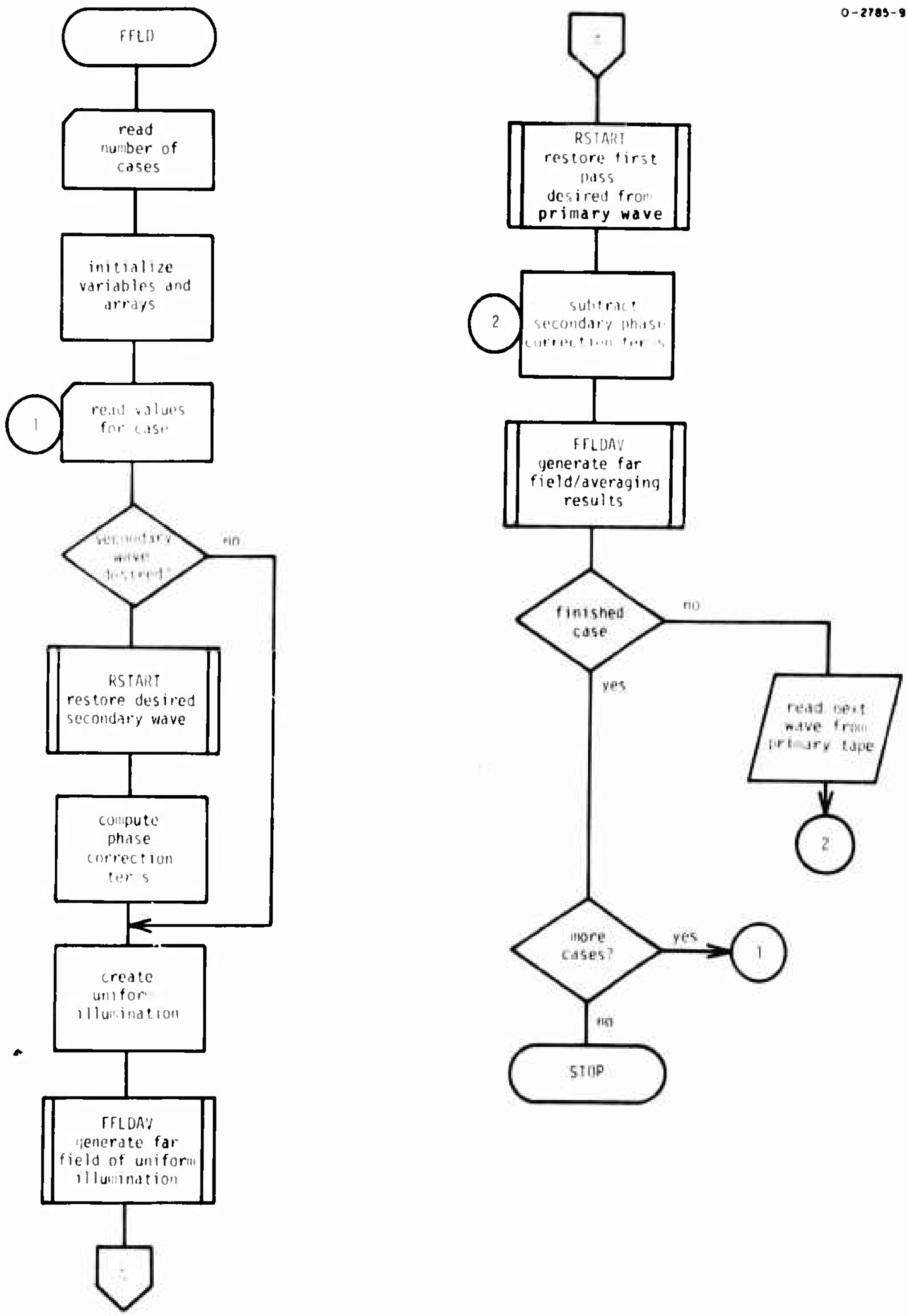


Fig. B2. FFLD logic flow diagram.

```
      PROGRAM FFLD(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
     +   TAPE12)
C                                                                       10100
      COMPLEX T(301,2),U(301,2),V(301,2),PMATFF(601),XMIR(301)          10120
C                                                                       10140
      DIMENSION INFOUT(101),IFFOPT(101),IFFOUT(101),STOTNF(301,2),      10160
     +   STOTFF(301,2),SO(301,21,2),XK0(2),SPHASE(301,2),K(301)         10180
C                                                                       10200
      COMMON /OT1/OUT1(301)/OT2/OUT2(301)/OT3/OUT3(301)                 10220
     +   /OT4/OUT4(301)/OT5/OUT5(301)/OT6/OUT6(301)/OT7/OUT7(301)       10240
      COMMON /FFNZ/ NZ                                                  10260
C                                                                       10280
      NAMELIST /CASENO/NCASES                                           10300
      NAMELIST /INITL/ASR,IPSTRT,IPFIN,ISTAG,NWAVES,IPCODE,             10320
     +   ISCODE,IFILE,ZLENFF,XK0,DX,NX,INFOUT,IFFOPT,IFFOUT,            10340
     +   TLOSS,REFL,RCURV,BETA,DIA1,DIA2,VR2,ZLEN                       10360
C                                                                       10362
      DATA NXDIM,NZDIM,NWDIM/301,21,2/                                  10365
C                                                                       10380
C           BEGIN RUN                                                   10400
C                                                                       10420
      READ(5,CASENO)                                                    10440
      DO 900 ICASE=1,NCASES                                             10460
C                                                                       10480
C         INITIALIZE NECESSARY VARIABLES AND ARRAYS                     10500
C                                                                       10520
      TOTNF=0.                                                          10540
      TOTFF=0.                                                          10560
      DO 30 I=1,101                                                     10680
      INFOUT(I)=0                                                       10700
      IFFOPT(I)=0                                                       10720
   30 IFFOUT(I)=0                                                       10740
C                                                                       10760
C           INITIALIZE INPUT VALUES FOR CASE                            10780
C                                                                       10800
   40 READ(5,INITL)                                                     10820
      DO 20 JWAVE=1,NWAVES                                              10580
      DO 20 I=1,NX                                                      10600
      STOTNF(I,JWAVE)=0.                                                10620
      STOTFF(I,JWAVE)=0.                                                10640
   20 CONTINUE                                                          10660
      NXC=DIA1/DX
      WRITE(IFILE,INITL)                                                10840
      IF(ASR.LE.0.) CALL PMAT30(NX,DX,ZLENFF,XK0,PMATFF)                10860
      CALL SETM01(NX,-NXC,XK0,0.,TLOSS,REFL,RCURV,BETA,DX,XMIR)         10880
C                                                                       10900
C          PRINT INITIAL VALUES FOR MIRROR                              10920
C                                                                       10940
      DO 45 I=1,NX                                                      10960
   45 X(I)=FLOAT(I-(NX+1)/2)*DX                                         10980
      CALL ALLOUT(IFILE,NX,1,3,18,18HMIRROR DESCRIPTION,                11000
     +   1,10,1,1HX,X,OUT1,                                             11020
     +   2,114,9,9HINTENSITY,XMIR,OUT2,                                 11040
     +   2,116,10,10HPHASE (DG),XMIR,OUT3)                              11060
C                                                                       11080
C            COMPUTE PHASE CORRECTION TERMS, IF REQUIRED                11100
C                                                                       11120
```

```
      IF(ISCODE.GT.0) CALL RSTART(IFILE,ISCODE,ISTAG,NWAVES,             11140
     +   NXDIM,NZDIM,U,SO)                                              11160
      DO 75 JWAVE=1,NWAVES                                              11180
      DO 50 I=1,NX                                                      11200
      SPHASE(I,JWAVE)=0.                                                11220
   50 IF(ISCODE.GT.0 .AND. REAL(U(I,JWAVE)).NE.0. .AND.                 11240
     +   AIMAG(U(I,JWAVE)).NE.0.)                                       11241
     +   SPHASE(I,JWAVE)=-ATAN2(AIMAG(U(I,JWAVE)),REAL(U(I,JWAVE)))     11260
      IF(ISCODE.GT.0 .AND. NWAVES.GT.1) WRITE(IFILE,9010)JWAVE          11261
   75 IF(ISCODE.GT.0) CALL ALLOUT(IFILE,NX,1,4,14,14HSECONDARY WAVE,    11262
     +   1,10,1,1HX,X,OUT1,                                             11264
     +   2,114,9,9HINTENSITY,U(1,JWAVE),OUT2,                           11266
     +   2,115,11,11HPHASE (RAD),U(1,JWAVE),OUT3,                       11268
     +   1,110,16,16HPHASE CORRECTION,SPHASE(1,JWAVE),OUT4)             11270
C                                                                       11272
C       CREATE INITIAL WAVEFORM FOR UNIFORM ILLUMINATION                11274
C                                                                       11276
      IF(VR2.GE.(1.E30)) DMAX=DIA2                                      11278
      IF(VR2.LT.(1.E30)) DMAX=(VR2+ZLEN)*DIA2/VR2                       11280
      IPTAG=0                                                           11282
      DO 90 I=1,NX                                                      11283
      U(I,1)=0.                                                         11284
      IF(ABS(X(I)).LE.(DMAX/2.)) U(I,1)=1.                              11285
   90 CONTINUE                                                          11286
      GO TO 200                                                         11287
C                                                                       11280
C             RESTORE PRIMARY WAVE                                      11300
C                                                                       11320
   95 IPTAG=MAX0(IPSTRT,1)
      CALL RSTART(IFILE,IPCODE,IPTAG,NWAVES,NXDIM,NZDIM,U,SO)
C                                                                       11380
C           SUBTRACT SECONDARY WAVE PHASE CORRECTION                    11400
C                                                                       11420
  100 CONTINUE                                                          11430
      IF(IPTAG.LE.0) GO TO 200                                          11435
      DO 150 JWAVE=1,NWAVES                                             11440
      DO 150 I=1,NX                                                     11460
  150 U(I,JWAVE)=U(I,JWAVE)*CMPLX(COS(SPHASE(I,JWAVE)),SIN(             11480
     +   SPHASE(I,JWAVE)))                                              11500
  200 WRITE(IFILE,9000)IPTAG                                            11510
C                                                                       11520
C        PRINT INITIAL WAVE(S), IF DESIRED                              11540
C                                                                       11560
      IF(IPTAG.GT.0 .AND. INFOUT(IPTAG).LE.0) GO TO 500                 11580
      DO 300 JWAVE=1,NWAVES                                             11600
      IF(IPTAG.LE.0 .AND. JWAVE.GT.1) GO TO 300
      IF(NWAVES.GT.1) WRITE(IFILE,9010) JWAVE                           11610
      CALL ALLOUT(IFILE,NX,1,3,15,15HNEAR FIELD WAVE,                   11620
     +   1,10,1,1HX,X,OUT1,                                             11640
     +   2,114,9,9HINTENSITY,U(1,JWAVE),OUT2,                           11660
     +   2,116,10,10HPHASE (DG),U(1,JWAVE),OUT3)                        11680
  300 CONTINUE                                                          11700
  500 CONTINUE                                                          11720
C                                                                       11740
C           CALL FAR FIELD/AVERAGING SUBROUTINE                         11760
C                                                                       11780
      IOPT=1                                                            11782
```

```
           IOUT=1                                                     11784
           NWS=1
           IF(IPTAG.GT.0) IOPT=IFFOPT(IPTAG)                          11786
           IF(IPTAG.GT.0) IOUT=IFFOUT(IPTAG)                          11788
           IF(IPTAG.GT.0) NWS=NWAVES
           CALL FFLDAV(IFILE,IOPT,IOUT,NX,NXDIM,NWS,
          +   ASR,ZLENFF,TOTNF,TOTFF,XKD,DX,T,U,V,                    11820
          +   XMIR,PMATFF,STOTNF,STOTFF)                              11840
           IF(IPTAG.GE.IPFIN) GO TO 800                               11860
      C                                                               11880
      C           IF DESIRED, RESTORE NEXT PRIMARY WAVE AND LOOP BACK 11900
      C                                                               11920
           IF(IPTAG.LE.0) GO TO 95                                    11930
           READ(IPCODE) ITAG                                          11940
           READ(IPCODE) ((U(I,J),I=1,NX),J=1,NWAVES)                  11960
           READ(IPCODE) (((SO(I,J,K),I=1,NX), J=1,NZ),K=1,NWAVES)     11980
           IPTAG=IPTAG+1                                              11990
           GO TO 100                                                  12000
      C                                                               12020
      C         CASE ENDED                                            12040
      C                                                               12060
       800 REWIND IPCODE                                              12070
           IF(ISCODE.GT.0) REWIND ISCODE                              12071
       900 CONTINUE                                                   12080
           STOP                                                       12100
      9000 FORMAT(1H1,13HSTARTING PASS,I5)                            12110
      9010 FORMAT(1H1,11HWAVE NUMBER,I5)                              12120
           END                                                        12120
                                                                      12140
```

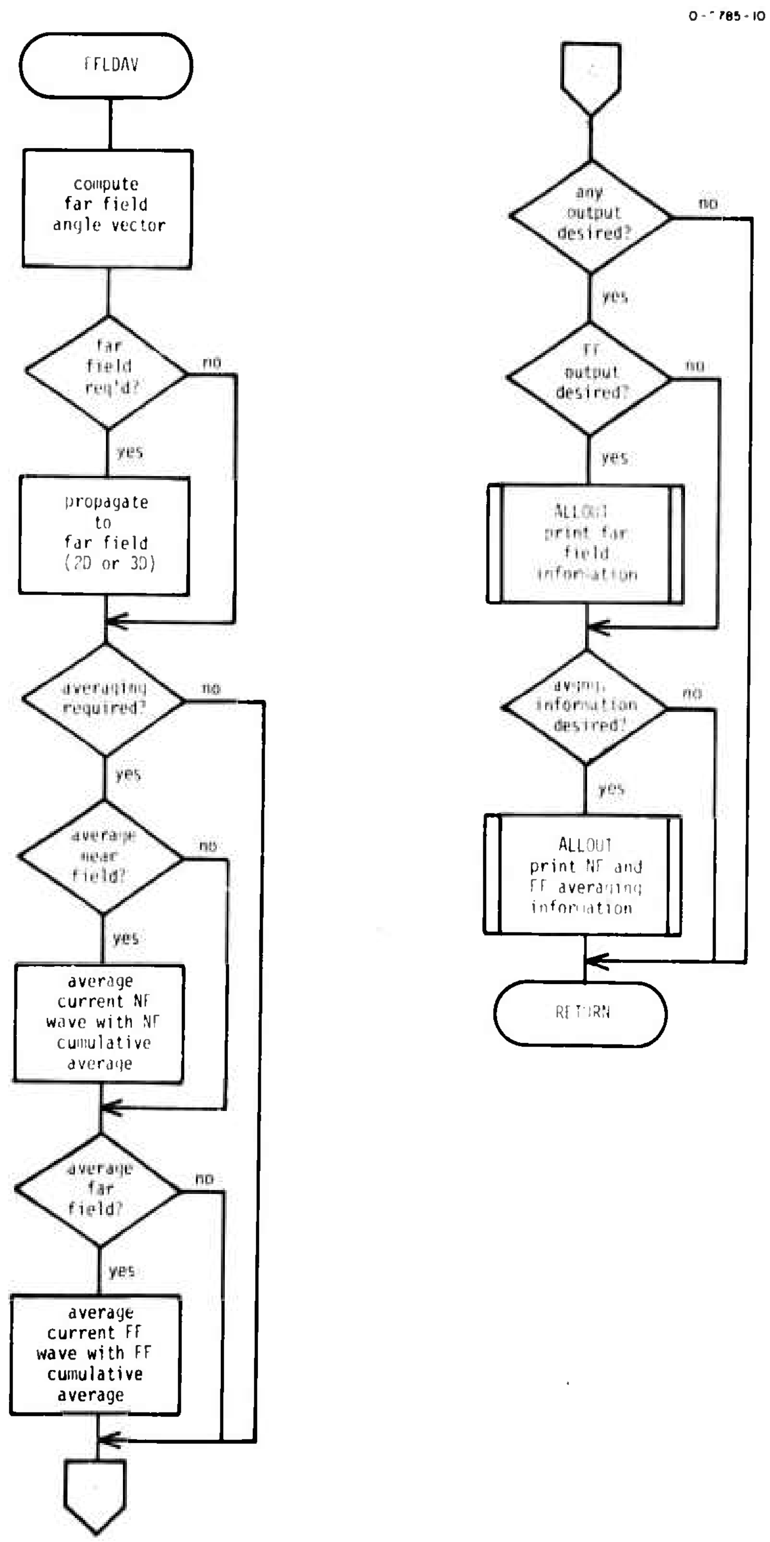


Fig. B3. FFLDAV logic flow diagram.

```
      SUBROUTINE FFLDAV(IFILE,IFFOPT,IFFOUT,NX,NXDIM,                   12160
     +   NWAVES,ASR,ZLENFF,TOTNF,TOTFF,XKO,DX,T,U,V,XMIRFF,PMATFF,      12180
     +   STOTNF,STOTFF)                                                 12200
      COMPLEX U(NXDIM,NWAVES),V(NXDIM,NWAVES),XMIRFF(NX),PMATFF(1),A    12220
      COMPLEX T(NXDIM,NWAVES)                                           12225
      DIMENSION XKO(NWAVES),STOTNF(NXDIM,NWAVES),STOTFF(NXDIM,NWAVES)   12240
      COMMON /OT1/OUT1(1)/OT2/OUT2(1)/OT3/OUT3(1)/OT4/OUT4(1)           12260
      COMMON /OT5/OUT5(1)/OT6/OUT6(1)/OT7/OUT7(1)                       12280
      XINTY(A)=REAL(A)**2+AIMAG(A)**2                                   12300
C                                                                       12320
C------------------------------------------------------------           12340
C   FFLDAV   FAR FIELD PROPAGATION, NF AND FF PROP AND AVERAGING,       12360
C            FAR FIELD AND AVERAGING OUTPUT                             12380
C------------------------------------------------------------           12400
C   THE PARAMETERS ARE                                                  12420
C                                                                       12440
C IFILE  OUTPUT FILE CODE                                               12460
C IFFOPT FF PROP AND NF/FF AVERAGING OPTION                             12480
C    .LE. 0   DON"T PROP, DON"T AVERAGE                                 12500
C    .EQ. 1   PROP, DON"T AVERAGE                                       12520
C    .EQ. 2   DON"T PROP, AVERAGE NF ONLY                               12540
C    .EQ. 3   PROP, AVERAGE NF ONLY                                     12560
C    .EQ. 4   PROP, AVERAGE FF ONLY                                     12580
C    .GE. 5   PROP, AVERAGE BOTH NF AND FF                              12600
C IFFOUT FAR FIELD/AVERAGING OUTPUT OPTION                              12620
C    .EQ. 0   DON"T PRINT                                               12640
C    .EQ. 1   PRINT ONLY FF INFORMATION                                 12660
C    .EQ. 2   PRINT ONLY AVERAGING INFORMATION                          12680
C    .EQ. 3   PRINT BOTH FF AND AVERAGING INFORMATION                   12700
C NX     THE NUMBER OF PROPAGATING POINTS                               12720
C NXDIM  THE X-DIMENSION OF THE PRINCIPAL MATRICES                      12740
C NWAVES THE NUMBER OF PROPAGATING WAVES                                12760
C ASR    3D PROPAGATION SWITCH                                          12780
C ZLENFF THE FAR FIELD PROPAGATION DISTANCE                             12800
C TOTNF  THE CURRENT NUMBER OF NF AVERAGES TAKEN                        12820
C TOTFF  THE CURRENT NUMBER OF FF AVERAGES TAKEN                        12840
C XKO    K=2*PI/LAMBDA, FOR EACH WAVE                                   12860
C DX     DELTA-X                                                        12880
C T      A DUMMY MATRIX                                                 12900
C U      THE NF PROPAGATION MATRIX (SUPP.)                              12920
C V      A DUMMY MATRIX--RETURNS FF VALUES (RET.)                       12940
C XMIRFF FF MIRROR VECTOR (SUPP.)                                       12960
C PMATFF FF FRESNEL PROPAGATION VECTOR (SUPP.)                          12980
C STOTNF NF AVERAGED INTENSITY MATRIX (SUPP./RET.)                      13000
C STOTFF FF AVERAGED INTENSITY MATRIX (SUPP./RET.)                      13020
C                                                                       13040
C   COMMON REQUIRED--OT1 THROUGH OT7 FOR OUTPUT PURPOSES                13060
C                                                                       13080
C   SUBPROGRAMS REQUIRED--ALLOUT,AREA21,FFPRP2                          13100
C                                                                       13120
C   CREATED 4/10/73                                                     13140
C   CHANGED 4/18/73 (POWER OUTPUT ADDED)                                13160
C   CHANGED 9/6/73   3D OPTION ADDED                                    13180
C  CHANGED 9/19/73 (ALL WAVES AVERAGED TOGETHER INCOHERENTLY)           13190
C-----------------------------------------------------------------      13200
C                                                                       13220
C                                                                       13240
```

```
C       COMPUTE FAR FIELD ANGLE, IN MILLIRADIANS                     13260
C                                                                    13280
      NCENT=(NX+1)/2                                                 13300
      DO 1000 I=1,NX                                                 13320
 1000 OUT1(I)=FLOAT(I-NCENT)*DX/ZLENFF*1000.                         13340
      IF(IFFOPT.LE.0 .OR. IFFOPT.EQ.2) GO TO 3000                    13360
C                                                                    13380
C           PROPAGATE TO FAR FIELD                                   13400
C                                                                    13420
      IF(ASR.GT.0.) GO TO 2500                                       13440
C---------2D FAR FIELD-----------------                              13460
      DO 2000 I=1,NWAVES                                             13480
      DO 2000 J=1,NX                                                 13500
      V(J,I)=0.                                                      13520
      DO 2000 K=1,NX                                                 13540
      L=NX-J+K                                                       13560
      V(J,I)=V(J,I)+U(K,I)*XMIRFF(K)*PMATFF(L)                       13580
 2000 CONTINUE                                                       13600
      GO TO 3000                                                     13620
C-----------3D FAR FIELD------------------                           13640
 2500 DO 2700 JWAVE=1,NWAVES                                         13660
      DO 2700 I=1,NX                                                 13680
 2700 T(I,JWAVE)=U(I,JWAVE)*XMIRFF(I)                                13700
      CALL FFPRP2(NX,ZLENFF,DX,XK0,T,V)                              13720
C                                                                    13740
C            ENSEMBLE AVERAGING, IF DESIRED                          13760
C                                                                    13780
 3000 IF(IFFOPT.LE.1) GO TO 5000                                     13800
      IF(IFFOPT.NE.4) TOTNF=TOTNF+1.                                 13820
      IF(IFFOPT.GE.4) TOTFF=TOTFF+1.                                 13840
      DO 4000 J=1,NX                                                 13880
      XTEMPU=0.                                                      13882
      XTEMPV=0.                                                      13883
      DO 3500 I=1,NWAVES                                             13884
      XTEMPU=XTEMPU+XINTY(U(J,I))                                    13885
 3500 XTEMPV=XTEMPV+XINTY(V(J,I))                                    13886
      IF(IFFOPT.NE.4)                                                13900
     +   STOTNF(J,1)=(XTEMPU+STOTNF(J,1)*(TOTNF-1.))/TOTNF           13920
      IF(IFFOPT.GE.4)                                                13940
     +   STOTFF(J,1)=(XTEMPV+STOTFF(J,1)*(TOTFF-1.))/TOTFF           13960
 4000 CONTINUE                                                       13980
C                                                                    14000
C              OUTPUT, IF DESIRED                                    14020
C                                                                    14040
 5000 IF(IFFOUT.LE.0) GO TO 9999                                     14060
      IF(IFFOUT.EQ.2) GO TO 7000                                     14080
C-----------FAR FIELD PRINTOUT--------------                         14100
      DO 6000 IWAVE=1,NWAVES                                         14120
      IF(NWAVES.GT.1) WRITE(IFILE,9020) IWAVE                        14130
      CALL ALLOUT(IFILE,NX,1,7,17,17HFAR FIELD RESULTS ,             14140
     +   1,10,12,12HTHETA (MRAD) ,OUT1,OUT1,                         14160
     +   2,113,9,9HMAGNITUDE ,V(1,IWAVE),OUT2,                       14180
     +   2,114,9,9HINTENSITY ,V(1,IWAVE),OUT3,                       14200
     +   2,220213,10,10HNORM. MAG. ,V(1,IWAVE),OUT4,                 14220
     +   2,220214,10,10HNORM. INT. ,V(1,IWAVE),OUT5,                 14240
     +   2,110215,11,11HNORM. PHASE ,V(1,IWAVE),OUT6,                14260
     +   2,1000214,10,10HNORM. AREA ,V(1,IWAVE),OUT7)                14280
```

```
 6000 CONTINUE
      WRITE(IFILE,9000)
      DO 6100 IWAVE=1,NWAVES
      CALL AREA21(0,NX,NXDIM,1,2,1,1HX,DX,V(1,IWAVE),ASR,AREA2D,AREA3D)
      IF(ASR.GT.0.) AREA2D=AREA3D
      WRITE(IFILE,9010) IWAVE,AREA2D
 6100 CONTINUE
      IF(IFFOUT.EQ.1) GO TO 9999
C-----------AVERAGING PRINTOUT---------------
 7000 IWAVE=1
      DO 7200 I=1,NX
 7200 OUT6(I)=FLOAT(I-NCENT)*DX
      CALL ALLOUT(IFILE,NX,1,6,9,9HAVERAGING ,
     +   1,10,1,1HX,OUT6,OUT6,
     +   1,10,12,12HTHETA (MRAD) ,OUT1,OUT1,
     +   1,111,12,12HNF INTENSITY ,STOTNF(1,IWAVE),OUT2,
     +   1,1000111,12,12HNF NORM AREA ,STOTNF(1,IWAVE),OUT3,
     +   1,11,12,12HFF INTENSITY ,STOTFF(1,IWAVE),OUT4,
     +   1,1000011,12,12HFF NORM AREA ,STOTFF(1,IWAVE),OUT5)
      CALL ALLOUT(IFILE,NX,1,3,9,9HAVERAGING ,
     +   1,0,5,5HTHETA,OUT1,OUT1,
     +   1,100,12,12HFF INTENSITY ,OUT4,OUT4,
     +   1,100,12,12HFF NORM AREA ,OUT5,OUT5)
 8000 CONTINUE
C
C             EXIT
C
 9999 RETURN
 9000 FORMAT(1H1,15HFAR FIELD POWER )
 9010 FORMAT(10X,11HWAVE NUMBER ,I3,E20.7)
 9020 FORMAT(1H1,11HWAVE NUMBER,I5)
      END
```

```
      SUBROUTINE PMAT30(NX,DX,ZLEN,XK0,PMAT)
      COMPLEX PMAT(1)
      DATA PI/3.14159265/
C
C-------------------------------------------------------------
C PMAT30  FRESNEL PROPAGATION MATRIX GENERATOR (FOX AND LI
C           APPROXIMATION) FOR PR30 ROUTINES
C-------------------------------------------------------------
C   THE PARAMETERS ARE
C
C NX     THE NUMBER OF POINTS TO BE PROPAGATED
C DX     DELTA X FOR PROPAGATION MATRIX
C ZLEN   PROPAGATION LENGTH
C XK0    WAVE NUMBER ( K = 2*PI/LAMBDA)
C PMAT   PROPAGATION MATRIX TO BE FORMED (DIM. 2*NX-1)
C
C   NO SUBPROGRAMS REQUIRED
C
C   CREATED 2-5-73
C-------------------------------------------------------------
C
C---DEFINE MULTIPLIER CONSTANTS (T1 AND T2)---
      T1=DX*SQRT(XK0/(PI*ZLEN))/2.
      T2=XK0*DX*DX/(2.*ZLEN)
C---DEFINE PROPAGATION MATRIX---
      DO 100 I=1,NX
      T6=FLOAT((I-1)*(I-1))*T2
      T7=COS(T6)
      T8=SIN(T6)
      J1=NX+1-I
      J2=NX+I-1
      PMAT(J1)=T1*CMPLX(T7+T8,T8-T7)
  100 PMAT(J2)=PMAT(J1)
      RETURN
      END
```

```
      SUBROUTINE FFPRP2(NN,XLEN,DR,XK0,U,V)
      COMPLEX U(1),COEF1,COEF2,V1,V2,COEF3,V(1),VC
      IC=(NN+1)/2
      JC=(NN-1)/2
      COEF1=-XK0/(2.*XLEN)*DR*(0.,1.)
      DO 100 JJ=1,JC
      J1=IC-JJ
      J2=IC+JJ
      R=DR*FLOAT(JJ)
      COEF2=CEXP((0.,1.)*XK0*R*R/(2.*XLEN))
      V1=U(IC)
      V2=U(IC)
      DO 50 II=1,JC
      I1=IC-II
      I2=IC+II
      RPRIME=DR*FLOAT(II)
      COEF3=RPRIME*CEXP((0.,1.)*XK0*RPRIME*RPRIME/(2.*XLEN))
      ARG=XK0*R*RPRIME/XLEN
      CALL BESJ(ARG,0,TERMJ,1.E-4,IER)
      TERMH=STRUVE(ARG)
      V1=V1+(U(I1)*(TERMJ-(0.,1.)*TERMH)
     +  +U(I2)*(TERMJ+(0.,1.)*TERMH))*COEF3
   50 V2=V2+(U(I1)*(TERMJ+(0.,1.)*TERMH)
     +  +U(I2)*(TERMJ-(0.,1.)*TERMH))*COEF3
      V(J1)=COEF1*COEF2*V1
  100 V(J2)=COEF1*COEF2*V2
      VC=U(IC)
      DO 300 II=1;JC
      RPRIME=DR*FLOAT(II)
      COEF3=RPRIME*CEXP((0.,1.)*XK0*RPRIME*RPRIME/(2.*XLEN))
      I1=IC-II
      I2=IC+II
  300 VC=VC+(U(I1)+U(I2))*COEF3
      V(IC)=VC*COEF1
      RETURN
      END
```

```
            FUNCTION STRUVE(Z)                                     16480
            RATIO=1./Z                                             16500
            STRUVE=0.                                              16520
            DO 100 I=1,1000,2                                      16540
            RATIO=RATIO*Z*Z/FLOAT(I*I)                             16560
            TERM=(-1.)**((I+1)/2+1)*RATIO                          16580
            STRUVE=STRUVE+TERM                                     16600
            IF(ABS(TERM).LT.(1.E-8)) GO TO 500                     16620
      100   CONTINUE
            WRITE(6,1000)                                          16640
     1000   FORMAT(1H0,33HSTRUVE FUNCTION DOES NOT CONVERGE)       16660
            RETURN                                                 16680
      500   STRUVE=STRUVE*.63661977                                16700
            RETURN                                                 16720
            END                                                    16740
                                                                   16760
                                                                   16780
```

```
      SUBROUTINE SETM01(NX,NXC,XK0,OMEGA,TLOSS,REFL,RCURV,BETA,DX,XM)
      COMPLEX XM(NX),CURV,TILT
C
C-----------------------------------------------------------------
C   SETM01    SETS UP A MIRROR VECTOR
C-----------------------------------------------------------------
C   THE PARAMETERS ARE
C NX      THE NUMBER OF POINTS TO BE SET UP
C NXC     THE NUMBER OF INTERVALS ACROSS THE MIRROR CENTER
C   .LT. 0    FAR FIELD MIRROR ASSUMED
C   .GT. 0    NEAR FIELD MIRROR ASSUMED
C XK0     K = 2 PI / LAMBDA
C OMEGA   N.F. MIRROR EDGE FALLOFF PARAMETER
C TLOSS   F.F. MIRROR LOSS (POWER)
C REFL    MIRROR REFLECTIVITY (POWER)
C RCURV   MIRROR RADIUS OF CURVATURE
C BETA    MIRROR TILT ANGLE
C DX      DELTA-X
C XM      MIRROR VECTOR (COMPLEX, DIM. AT LST NX)
C
C   SUBPROGRAMS REQUIRED--NONE
C
C   CREATED 4-3-73 FROM SETMIR (PR20 ROUTINE)
C   CHANGED 4-9-73 (MIRROR EDGES REDEFINED, END POINTS ADDED)
C   CHANGED 9/6/73    DX USED INSTEAD OF X-ARRAY
C-------------------------------------------------------
C
      ICENT=(NX+1)/2
      NXCP1=ICENT-(IABS(NXC)+1)/2
      NXCP2=ICENT+(IABS(NXC)+1)/2
C
C           DEFINE MIRROR VALUE FOR EACH MATRIX LOCATION
C
      DO 140 J=1,NX
C-------------DETERMINE RADIUS OF CURVATURE COMPONENT---------
      IF(RCURV.GE.(1.E30)) CURV=1.
      IF(RCURV.LT.(1.E30)) CURV=
     +   CEXP(-XK0*(FLOAT(J-ICENT)*DX)**2*(0.,1.)/RCURV)
C-----------DETERMINE MIRROR TILT COMPONENT---------------
      TILT=CEXP(2.*XK0*BETA*(FLOAT(J-ICENT)*DX)*(0.,1.))
C---------DETERMINE NEAR FIELD MIRROR REFLECTIVITY COMPONENT----------
      IF(NXC.LT.0) GO TO 100
      RFLEC=0.
      IF(J.GE.NXCP1.AND.J.LE.NXCP2) RFLEC=1.
      IF(OMEGA.NE.0. .AND. J.LT.NXCP1) RFLEC=
     +   EXP(-(FLOAT(NXCP1-J)*DX/OMEGA)**2)
      IF(OMEGA.NE.0. .AND. J.GT.NXCP2) RFLEC=
     +   EXP(-(FLOAT(J-NXCP2)*DX/OMEGA)**2)
      RFLEC=SQRT(REFL)*RFLEC
      GO TO 130
C--------DETERMINE FAR FIELD MIRROR REFLECTIVITY COMPONENT--------
 100  IF(J.LT.NXCP1 .OR. J.GT.NXCP2) RFLEC=1.
      IF(J.GE.NXCP1 .AND. J.LE.NXCP2) RFLEC=
     +   SQRT(1.-REFL)*SQRT(1.-TLOSS)
C-------------COMPUTE MIRROR VECTOR VALUE-----------------
 130  XM(J)=RFLEC*CURV*TILT
 140  CONTINUE
```

```
C-------REDEFINE MIRROR END POINTS TO HALF THEIR VALUE-----------
        IF(NXC.GT.0) XM(NXCP1)=XM(NXCP1)/2.
 60     IF(NXC.GT.0) XM(NXCP2)=XM(NXCP2)/2.
        RETURN
        END
```

D. Sample Case for FFP

The case described by the input below is a far-field analysis of the waveforms computed during the sample case "8.45" described in Appendix D. A magnetic tape was generated and saved by that program and will be used for input to the FFP. The user is assumed to be familiar with the conventions adopted by his own computer center when referencing a previously saved magnetic tape.

The far-field analysis is to be two-dimensional (ASR = 0.) adhering to the same mode of analysis used in the SSCP(ECS) sample case 8.45. The tape is to be read from its beginning, rather than some intermediate pass number, and is to read no further than the 7^{th} pass. One wave is to be taken from the tape at each pass (the tape could contain more waves). The file code for the primary wave is logical file code 10 (the user is assumed to have previously informed the computer system that file code 10 is to be associated with the SSCP restart tape). There is no secondary, or empty cavity, tape to furnish phase terms for subtraction from the primary waveforms. The file code for normal program output is logical file code 6. The far-field propagation distance is to be 6×10^4 cm. The wave number (XK0) can be found in the fifth NAMELIST group (WAVES) at the beginning of the normal output of the SSCP(ECS) for case 8.45 following the vector name XKZERO. The Δx mesh spacing can similarly be found in the second NAMELIST block (CAVITY) following the term DXOUT. The number of mesh points along the x direction is known (from the input to 8.45) to be 81. The first seven passes read from the restart tape are to have their near field values printed, to be propagated to the far field, and to have the far field values printed. No averaging is to be performed. The output mirror of the 8.45 cavity is 100% reflecting (the loss has no meaning in this instance since no light energy passes through the mirror). The radius of curvature of the far field mirror is twice the propagation length above, or 12×10^4 cm. The far-field mirror is not tilted. The diameters of the output mirror and back

mirror for the 8.45 cavity are 5.74 cm and 11.1 cm, respectively. The virtual radius of the back mirror is found in the second, or CAVITY, NAMELIST group of case 8.45 after the term VR2. The distance between mirrors in the cavity is 10,000 cm.

Sample Input Deck

(column 2)

```
 $CASENO NCASES=1$
 $INITL
    ASR=0.,IPSTRT=0,IPFIN=7,NWAVES=1,
            IPCODE=10,ISCODE=0,ISTAG=0,
    IFILE=6,ZLENFF=6.E4,XK0(1)=20944.,
            DX=.225,NX=81,
    INFOUT(1)=7*1,IFFOPT(1)=7*1,IFFOUT(1)=7*1,
    TLOSS=0.,REFL=1.,RCURV=1.2E5,BETA=0.,
            DIA1=5.74,DIA2=11.1,VR2=1.E30,
            ZLEN=10000.$
```

The output produced by the FFP consists of four major groups. The first is not optional and includes the following:

1. Repetition of the input data

2. Description of the far-field mirror matrix (intensity and phase listings and plots)

3. Restart summary of titling information contained on the secondary tape, followed by a listing and plot of the phase correction information (appears only if a secondary wave, or empty cavity, tape is used)

4. Description of the "ideal" uniformly illuminated aperture for this cavity configuration

5. Far field summary of the wave in 4.

6. Restart summary of titling information contained on the primary tape

The near-field summary (optional) lists and plots the intensity and phase information of a wave taken from a primary tape (after phase correction, if a secondary tape was specified).

The far-field summary (optional) lists and plots magnitude, intensity, normalized magnitude, normalized intensity, normalized phase, and normalized area of a near-field wave.

The averaging summary (optional) lists and plots the incoherent average of both near-field and far-field waveforms.

The following pages represent the output produced by the sample data case. All types of output except the secondary wave restart and averaging are represented.

```
NAMELIST    INITL
ASR      0.
IPSTRT              0    IPFIN              7    ISTAG              0    NWAVES             1    IPCODE            10
ISCODE              0    IFILE              6
ZLENFF   0.60000000E 05
XKO   (I)
     1   0.20944000E 05   0.
DX       0.22500000E 00
NX                 81
INFOUT(I)
     1              1         1         1         1         1         1         1         0
     9              0         0         0         0         0         0         0         0
    17              0         0         0         0         0         0         0         0
    25              0         0         0         0         0         0         0         0
    33              0         0         0         0         0         0         0         0
    41              0         0         0         0         0         0         0         0
    49              0         0         0         0         0         0         0         0
    57              0         0         0         0         0         0         0         0
    65              0         0         0         0         0         0         0         0
    73              0         0         0         0         0         0         0         0
    81              0         0         0         0         0         0         0         0
    89              0         0         0         0         0         0         0         0
    97              0         0         0         0         0
IFFOPT(I)
     1              1         1         1         1         1         1         1         0
     9              0         0         0         0         0         0         0         0
    17              0         0         0         0         0         0         0         0
    25              0         0         0         0         0         0         0         0
    33              0         0         0         0         0         0         0         0
    41              0         0         0         0         0         0         0         0
    49              0         0         0         0         0         0         0         0
    57              0         0         0         0         0         0         0         0
    65              0         0         0         0         0         0         0         0
    73              0         0         0         0         0         0         0         0
    81              0         0         0         0         0         0         0         0
    89              0         0         0         0         0         0         0         0
    97              0         0         0         0         0
IFFOUT(I)
     1              1         1         1         1         1         1         1         0
     9              0         0         0         0         0         0         0         0
    17              0         0         0         0         0         0         0         0
    25              0         0         0         0         0         0         0         0
    33              0         0         0         0         0         0         0         0
    41              0         0         0         0         0         0         0         0
    49              0         0         0         0         0         0         0         0
    57              0         0         0         0         0         0         0         0
    65              0         0         0         0         0         0         0         0
    73              0         0         0         0         0         0         0         0
    81              0         0         0         0         0         0         0         0
    89              0         0         0         0         0         0         0         0
    97              0         0         0         0         0
TLOSS    0.                REFL    0.10000000E 01    RCURV   0.12000000E 06    BETA    0.
DIA1     0.57400000E 01    DIA2    0.11100000E 02    VR2     0.10000000E 31    ZLEN    0.10000000E 05
END   NAMELIST    INITL
```

MIRROR DESCRIPTION

I	X	INTENSITY	PHASE (DG)
1	-0.90000000E 01	0.10000000E 01	-0.90002237E 02
2	-0.87750000E 01	0.10000000E 01	-0.50008240E 02
3	-0.85500000E 01	0.10000000E 01	-0.11026748E 02
4	-0.83249999E 01	0.99999996E 00	0.26942243E 02
5	-0.81000000E 01	0.99999996E 00	0.63898710E 02
6	-0.78750000E 01	0.10000000E 01	0.99842885E 02
7	-0.76500000E 01	0.10000000E 01	0.13477415E 03
8	-0.74250000E 01	0.10000000E 01	0.16869311E 03
9	-0.72000000E 01	0.10000000E 01	-0.15840182E 03
10	-0.69750000E 01	0.10000000E 01	-0.12650787E 03
11	-0.67500000E 01	0.10000000E 01	-0.95626431E 02
12	-0.65250000E 01	0.99999998E 00	-0.65757497E 02
13	-0.63000000E 01	0.99999998E 00	-0.36901069E 02
14	-0.60750000E 01	0.99999999E 00	-0.90571454E 01
15	-0.58500000E 01	0.10000000E 01	0.17774270E 02
16	-0.56250000E 01	0.99999998E 00	0.43593178E 02
17	-0.54000000E 01	0.99999999E 00	0.68399585E 02
18	-0.51750000E 01	0.99999999E 00	0.92[illegible]93480E 02
19	-0.49500000E 01	0.10000000E 01	0.11497487E 03
20	-0.47250000E 01	0.10000000E 01	0.13674376E 03
21	-0.45000000E 01	0.99999999E 00	0.15750013E 03
22	-0.42750000E 01	0.10000000E 01	0.17724[illegible]01E 03
23	-0.40500000E 01	0.99999999E 00	-0.16402602E 03
24	-0.38250000E 01	0.99999999E 00	-0.14630715E 03
25	-0.36000000E 01	0.10000000E 01	-0.12960880E 03
26	-0.33750000E 01	0.10000000E 01	-0.11390695E 03
27	-0.31500000E 01	0.10000000E 01	-0.99225614E 02
28	-0.29250000E 01	0.	-0.50000000E 00
29	-0.27000000E 01	0.	-0.50000000E 00
30	-0.24750000E 01	0.	-0.50000000E 00
31	-0.22500000E 01	0.	-0.50000000E 00
32	-0.20250000E 01	0.	-0.50000000E 00
33	-0.18000000E 01	0.	-0.50000000E 00
34	-0.15750000E 01	0.	-0.50000000E 00
35	-0.13500000E 01	0.	-0.50000000E 00
36	-0.11250000E 01	0.	-0.50000000E 00
37	-0.90000000E 00	0.	-0.50000000E 00
38	-0.67500000E 00	0.	-0.50000000E 00
39	-0.45000000E 00	0.	-0.50000000E 00
40	-0.22500000E 00	0.	-0.50000000E 00
41	0.	0.	-0.50000000E 00
42	0.22500000E 00	0.	-0.50000000E 00
43	0.45000000E 00	0.	-0.50000000E 00
44	0.67500000E 00	0.	-0.50000000E 00
45	0.90000000E 00	0.	-0.50000000E 00
46	0.11250000E 01	0.	-0.50000000E 00
47	0.13500000E 01	0.	-0.50000000E 00
48	0.15750000E 01	0.	-0.50000000E 00
49	0.18000000E 01	0.	-0.50000000E 00
50	0.20250000E 01	0.	-0.50000000E 00

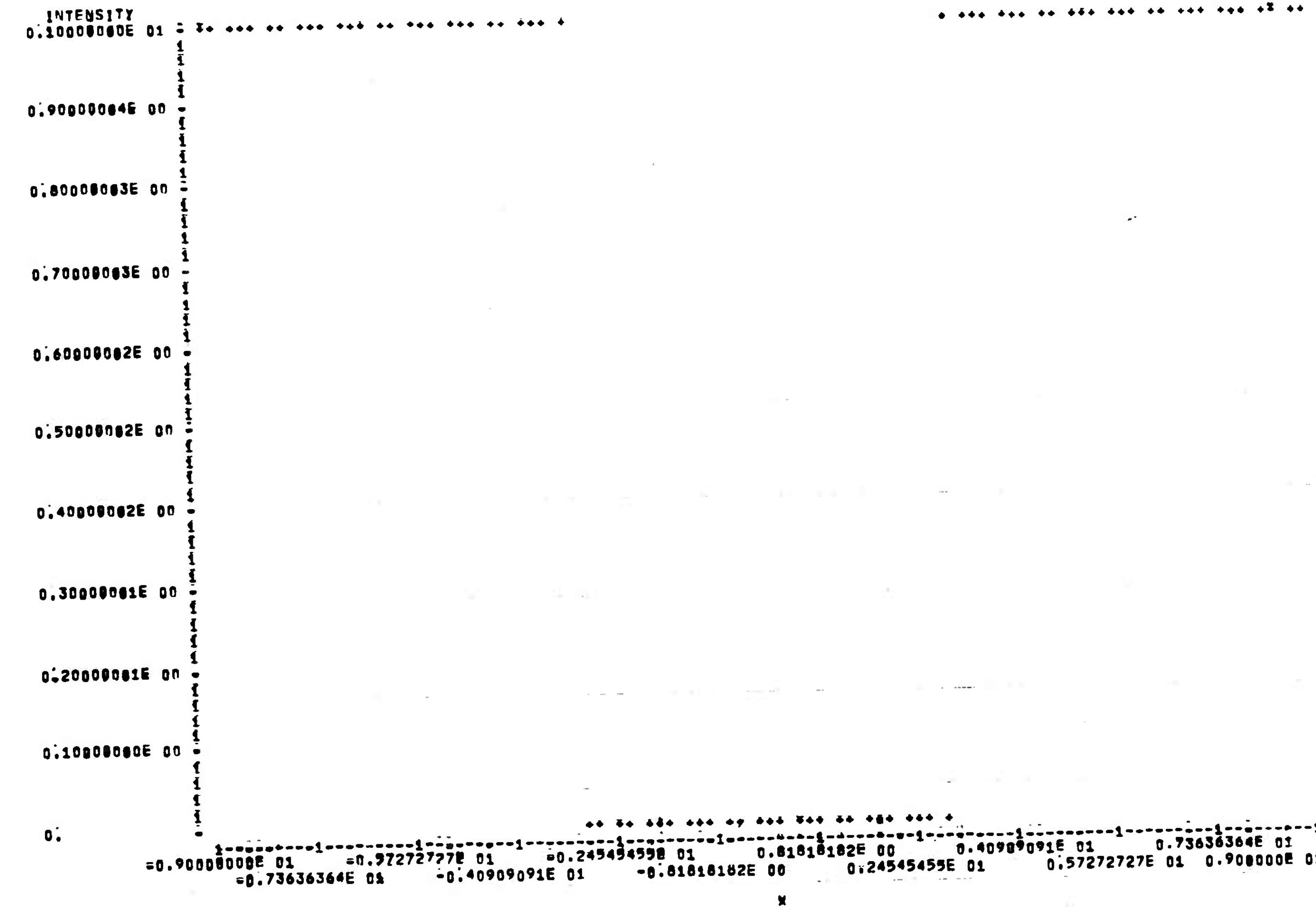
MIRROR DESCRIPTION

I	X	INTENSITY	PHASE (DG)
51	0.22500000E 01	0.	-0.50000000E 00
52	0.24750000E 01	0.	-0.50000000E 00
53	0.27000000E 01	0.	-0.50000000E 00
54	0.29250000E 01	0.	-0.50000000E 00
55	0.31500000E 01	0.10000000E 01	-0.99225614E 02
56	0.33750000E 01	0.10000000E 01	-0.11390895E 03
57	0.36000000E 01	0.10000000E 01	-0.12960080E 03
58	0.38250000E 01	0.99999999E 00	-0.14630715E 03
59	0.40500000E 01	0.99999999E 00	-0.16402602E 03
60	0.42750000E 01	0.10000000E 01	0.17724401E 03
61	0.45000000E 01	0.99999999E 00	0.15750013E 03
62	0.47250000E 01	0.10000000E 01	0.13674376E 03
63	0.49500000E 01	0.10000000E 01	0.11497487E 03
64	0.51750000E 01	0.99999999E 00	0.92193480E 02
65	0.54000000E 01	0.99999999E 00	0.68399585E 02
66	0.56250000E 01	0.99999998E 00	0.43593178E 02
67	0.58500000E 01	0.10000000E 01	0.17774270E 02
68	0.60750000E 01	0.99999999E 00	-0.90571454E 01
69	0.63000000E 01	0.99999998E 00	-0.36901869E 02
70	0.65250000E 01	0.99999998E 00	-0.65757497E 02
71	0.67500000E 01	0.10000000E 01	-0.95626431E 02
72	0.69750000E 01	0.10000000E 01	-0.12650787E 03
73	0.72000000E 01	0.10000000E 01	-0.15840182E 03
74	0.74250000E 01	0.10000000E 01	0.16869311E 03
75	0.76500000E 01	0.10000000E 01	0.13477415E 03
76	0.78750000E 01	0.10000000E 01	0.99842685E 02
77	0.81000000E 01	0.99999996E 00	0.63898710E 02
78	0.83249999E 01	0.99999996E 00	0.26942843E 02
79	0.85500000E 01	0.10000000E 01	-0.11026748E 02
80	0.87750000E 01	0.10000000E 01	-0.50008240E 02
81	0.90000000E 01	0.10000000E 01	-0.90002237E 02

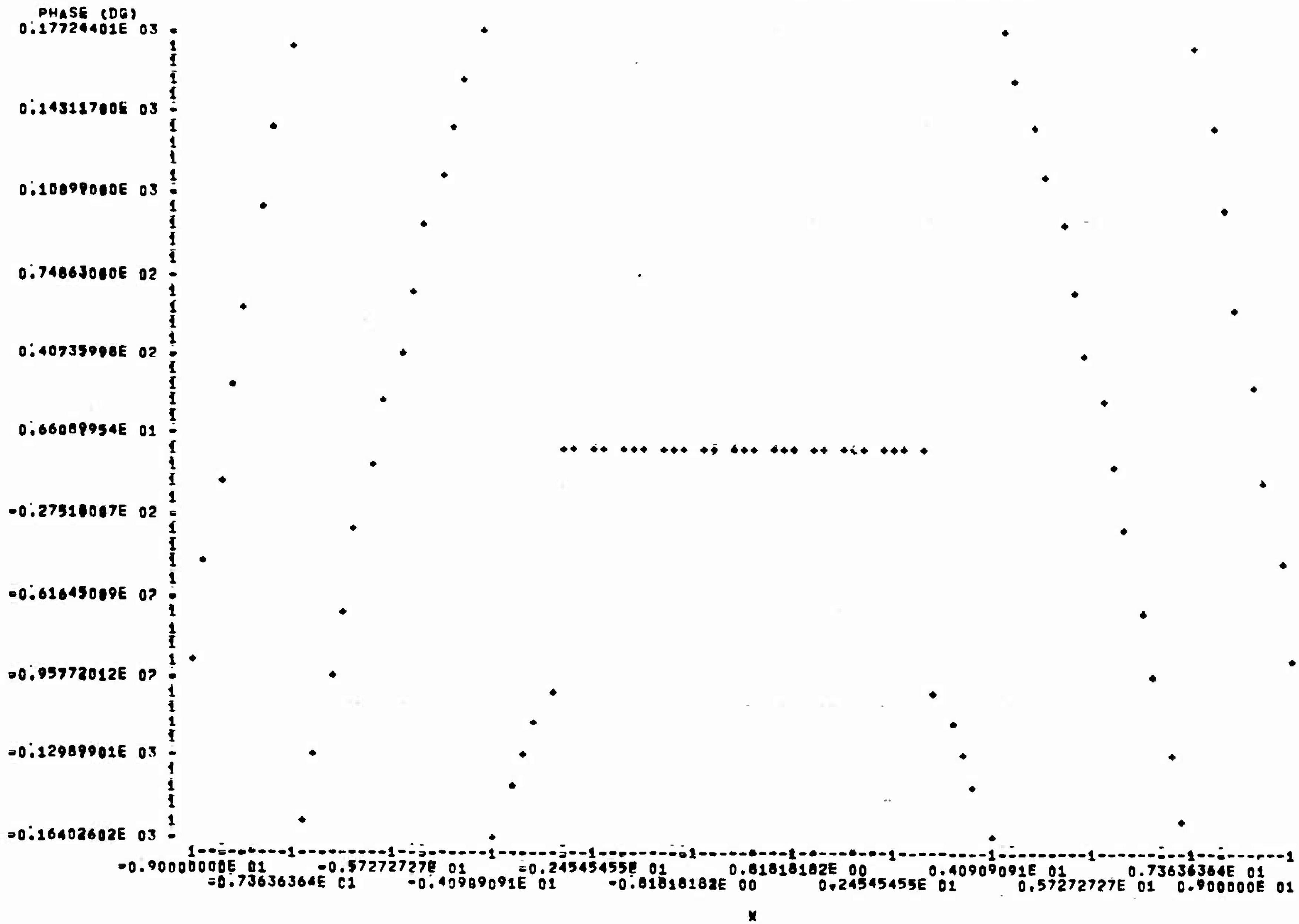
MIRROR DESCRIPTION
NUMBER OF POINTS= 81

X INCREMENT= 0.16363636E 00

Y INCREMENT= 0.20000001E-01



MIRROR DESCRIPTION
NUMBER OF POINTS= 81   X INCREMENT= 0.16363636E 00   Y INCREMENT= 0.68294004E 01



STARTING PASS 0

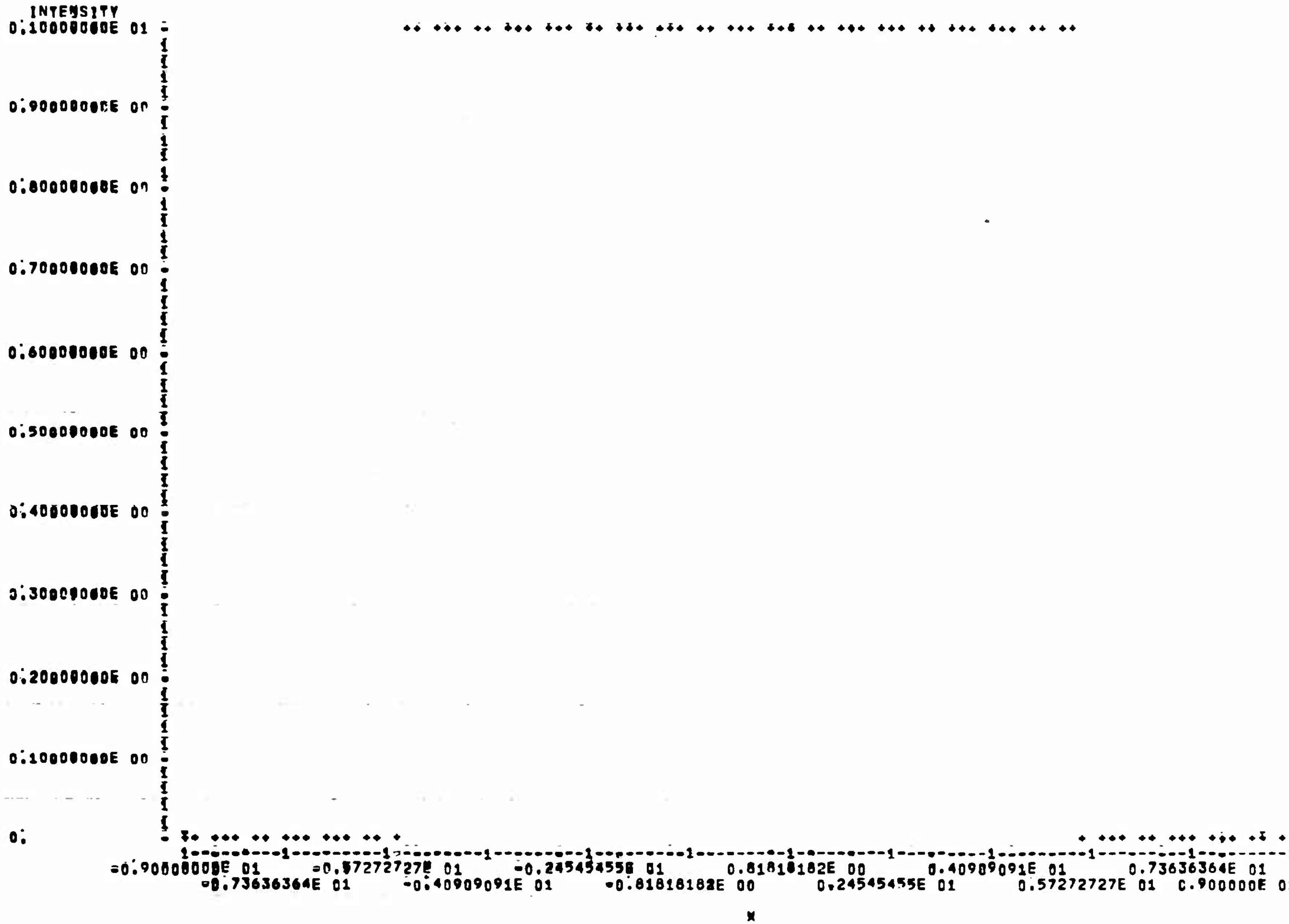
NEAR FIELD WAVE

I	X	INTENSITY	PHASE (DG)
1	-0.90000000E 01	0.	-0.50000000E 00
2	-0.87750000E 01	0.	-0.50000000E 00
3	-0.85500000E 01	0.	-0.50000000E 00
4	-0.83249999E 01	0.	-0.50000000E 00
5	-0.81000000E 01	0.	-0.50000000E 00
6	-0.78750000E 01	0.	-0.50000000E 00
7	-0.76500000E 01	0.	-0.50000000E 00
8	-0.74250000E 01	0.	-0.50000000E 00
9	-0.72000000E 01	0.	-0.50000000E 00
10	-0.69750000E 01	0.	-0.50000000E 00
11	-0.67500000E 01	0.	-0.50000000E 00
12	-0.65250000E 01	0.	-0.50000000E 00
13	-0.63000000E 01	0.	-0.50000000E 00
14	-0.60750000E 01	0.	-0.50000000E 00
15	-0.58500000E 01	0.	-0.50000000E 00
16	-0.56250000E 01	0.	-0.50000000E 00
17	-0.54000000E 01	0.10000000E 01	0.
18	-0.51750000E 01	0.10000000E 01	0.
19	-0.49500000E 01	0.10000000E 01	0.
20	-0.47250000E 01	0.10000000E 01	0.
21	-0.45000000E 01	0.10000000E 01	0.
22	-0.42750000E 01	0.10000000E 01	0.
23	-0.40500000E 01	0.10000000E 01	0.
24	-0.38250000E 01	0.10000000E 01	0.
25	-0.36000000E 01	0.10000000E 01	0.
26	-0.33750000E 01	0.10000000E 01	0.
27	-0.31500000E 01	0.10000000E 01	0.
28	-0.29250000E 01	0.10000000E 01	0.
29	-0.27000000E 01	0.10000000E 01	0.
30	-0.24750000E 01	0.10000000E 01	0.
31	-0.22500000E 01	0.10000000E 01	0.
32	-0.20250000E 01	0.10000000E 01	0.
33	-0.18000000E 01	0.10000000E 01	0.
34	-0.15750000E 01	0.10000000E 01	0.
35	-0.13500000E 01	0.10000000E 01	0.
36	-0.11250000E 01	0.10000000E 01	0.
37	-0.90000000E 00	0.10000000E 01	0.
38	-0.67500000E 00	0.10000000E 01	0.
39	-0.45000000E 00	0.10000000E 01	0.
40	-0.22500000E 00	0.10000000E 01	0.
41	0.	0.10000000E 01	0.
42	0.22500000E 00	0.10000000E 01	0.
43	0.45000000E 00	0.10000000E 01	0.
44	0.67500000E 00	0.10000000E 01	0.
45	0.90000000E 00	0.10000000E 01	0.
46	0.11250000E 01	0.10000000E 01	0.
47	0.13500000E 01	0.10000000E 01	0.
48	0.15750000E 01	0.10000000E 01	0.
49	0.18000000E 01	0.10000000E 01	0.
50	0.20250000E 01	0.10000000E 01	0.

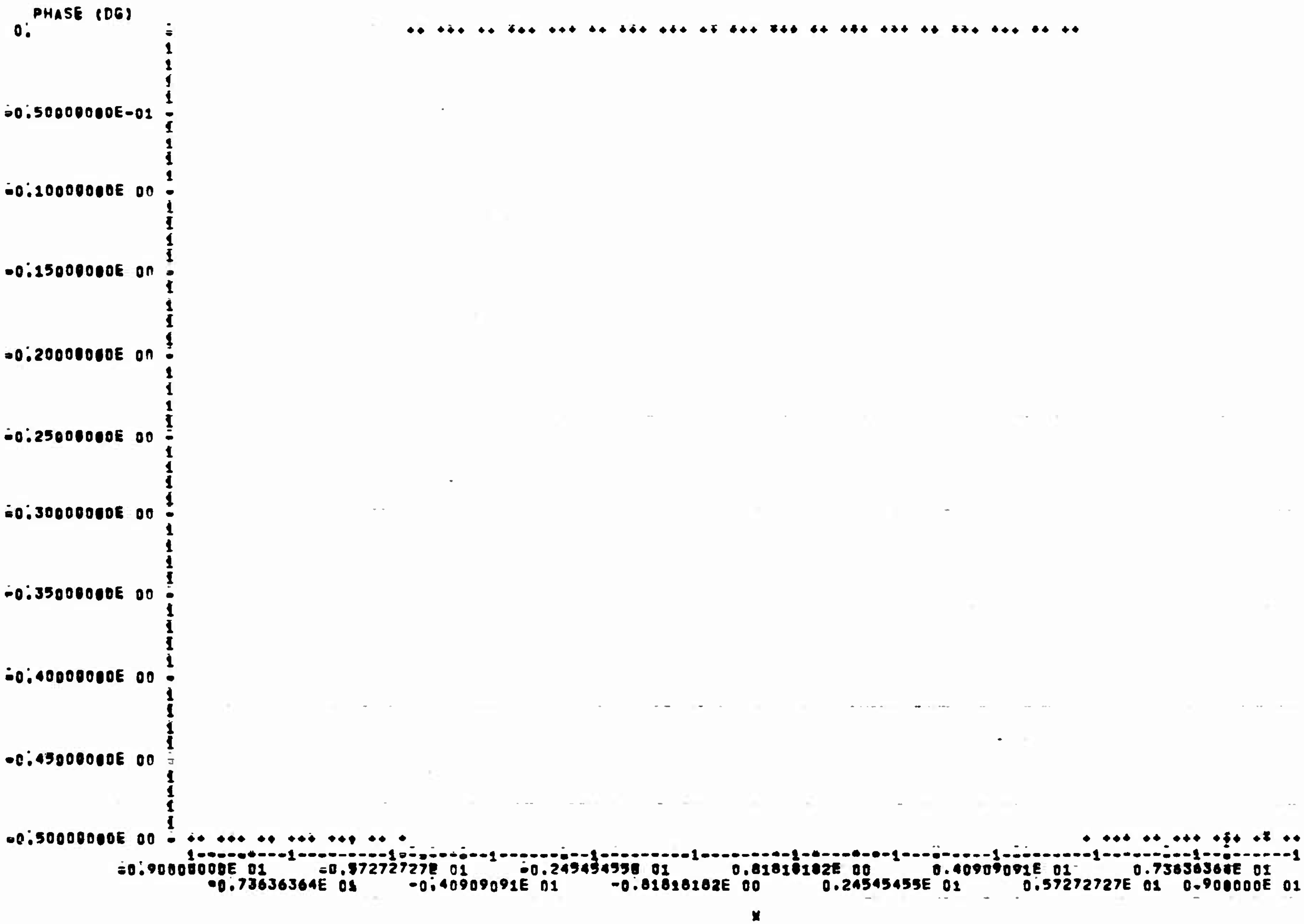
NEAR FIELD WAVE

I	X	INTENSITY	PHASE (DG)
51	0.22500000E 01	0.10000000E 01	0.
52	0.24750000E 01	0.10000000E 01	0.
53	0.27000000E 01	0.10000000E 01	0.
54	0.29250000E 01	0.10000000E 01	0.
55	0.31500000E 01	0.10000000E 01	0.
56	0.33750000E 01	0.10000000E 01	0.
57	0.36000000E 01	0.10000000E 01	0.
58	0.38250000E 01	0.10000000E 01	0.
59	0.40500000E 01	0.10000000E 01	0.
60	0.42750000E 01	0.10000000E 01	0.
61	0.45000000E 01	0.10000000E 01	0.
62	0.47250000E 01	0.10000000E 01	0.
63	0.49500000E 01	0.10000000E 01	0.
64	0.51750000E 01	0.10000000E 01	0.
65	0.54000000E 01	0.10000000E 01	0.
66	0.56250000E 01	0.	-0.50000000E 00
67	0.58500000E 01	0.	-0.50000000E 00
68	0.60750000E 01	0.	-0.50000000E 00
69	0.63000000E 01	0.	-0.50000000E 00
70	0.65250000E 01	0.	-0.50000000E 00
71	0.67500000E 01	0.	-0.50000000E 00
72	0.69750000E 01	0.	-0.50000000E 00
73	0.72000000E 01	0.	-0.50000000E 00
74	0.74250000E 01	0.	-0.50000000E 00
75	0.76500000E 01	0.	-0.50000000E 00
76	0.78750000E 01	0.	-0.50000000E 00
77	0.81000000E 01	0.	-0.50000000E 00
78	0.83249999E 01	0.	-0.50000000E 00
79	0.85500000E 01	0.	-0.50000000E 00
80	0.87750000E 01	0.	-0.50000000E 00
81	0.90000000E 01	0.	-0.50000000E 00

NEAR FIELD WAVE
NUMBER OF POINTS= 81 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.20000000E-01



NEAR FIELD WAVE
NUMBER OF POINTS= 51 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.10000000E-01

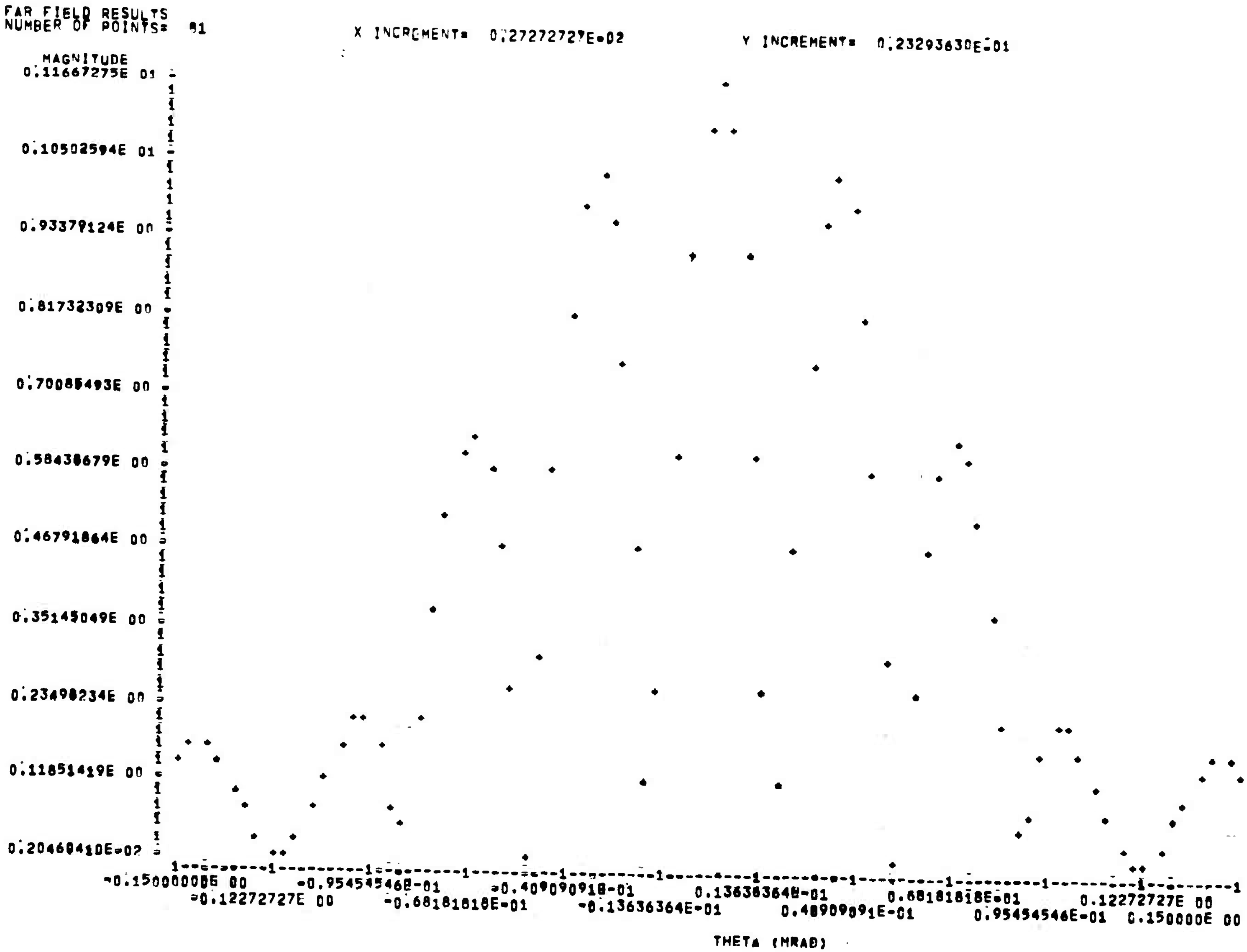


FAR FIELD RESULTS

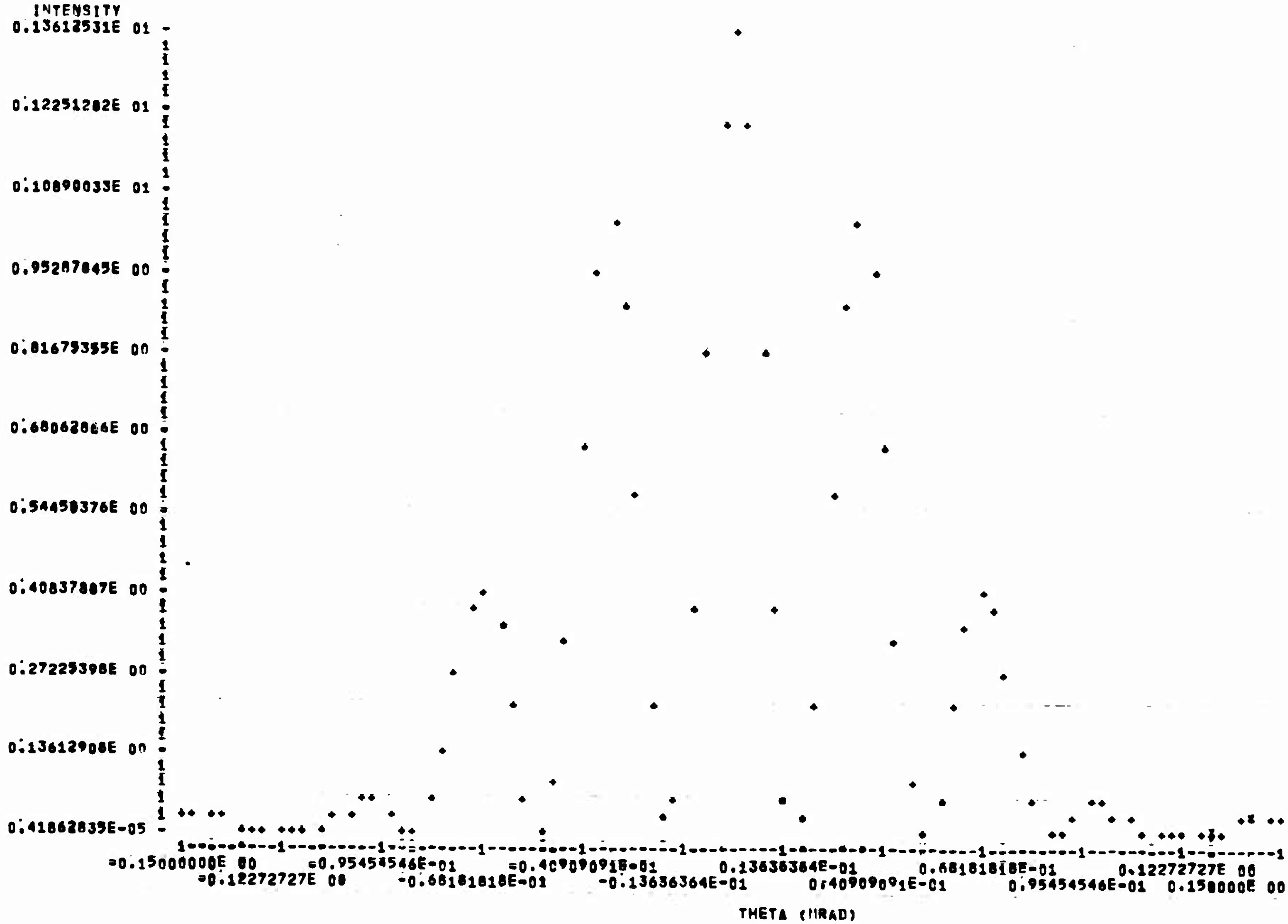
I	THETA (MRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
1	-0.15000000E 00	0.13509147E 00	0.18249705E-01	0.11578665E 00	0.13406547E-01	-0.15707632E 01	0.99818729E 00
2	-0.14625000E 00	0.16388962E 00	0.26859807E-01	0.14046949E 00	0.19731677E-01	-0.22687875E 01	0.99551935E 00
3	-0.14250000E 00	0.16562559E 00	0.27431835E-01	0.14195738E 00	0.20151898E-01	0.33340452E 01	0.99279458E 00
4	-0.13875000E 00	0.14353220E 00	0.20601493E-01	0.12302119E 00	0.15134212E-01	0.26713639E 01	0.99074827E 00
5	-0.13500000E 00	0.10527840E 00	0.11083542E-01	0.90233923E-01	0.81421608E-02	0.20263540E 01	0.98964736E 00
6	-0.13125000E 00	0.61500767E-01	0.37823443E-02	0.52712193E-01	0.27785753E-02	0.13990157E 01	0.98927166E 00
7	-0.12750000E 00	0.23726006E-01	0.56292336E-03	0.20335916E-01	0.41353320E-03	0.78934871E 00	0.98921575E 00
8	-0.12375000E 00	0.20460411E-02	0.41862843E-05	0.17536981E-02	0.30753166E-05	0.19735093E 00	0.98921534E 00
9	-0.12000000E 00	0.29687870E-02	0.88136962E-05	0.25445418E-02	0.64746931E-05	-0.37697390E 00	0.98921446E 00
10	-0.11625000E 00	0.27855416E-01	0.77592420E-03	0.23874825E-01	0.57000729E-03	-0.93362282E 00	0.98913739E 00
11	-0.11250000E 00	0.72269198E-01	0.52228369E-02	0.61941795E-01	0.38367860E-02	-0.14726033E 01	0.98861861E 00
12	-0.10875000E 00	0.12641162E 00	0.15979898E-01	0.10834717E 00	0.11739108E-01	-0.19939124E 01	0.98703136E 00
13	-0.10500000E 00	0.17663475E 00	0.31199834E-01	0.15139331E 00	0.22919935E-01	0.37856351E 01	0.98393232E 00
14	-0.10125000E 00	0.20782315E 00	0.43190460E-01	0.17812483E 00	0.31728456E-01	0.32996690E 01	0.97964229E 00
15	-0.97500000E-01	0.20627031E 00	0.42547440E-01	0.17679390E 00	0.31256082E-01	0.28313743E 01	0.97541012E 00
16	-0.93750000E-01	0.16256248E 00	0.26426561E-01	0.13933200E 00	0.19413407E-01	0.23807511E 01	0.97279120E 00
17	-0.90000000E-01	0.73950360E-01	0.54686557E-02	0.63382716E-01	0.40173687E-02	0.19477994E 01	0.97224801E 00
18	-0.86250000E-01	0.54254986E-01	0.29436036E-02	0.46501848E-01	0.21624219E-02	-0.16090739E 01	0.97195563E 00
19	-0.82500000E-01	0.20858594E 00	0.43508095E-01	0.17877862E 00	0.31961796E-01	-0.20068824E 01	0.96763404E 00
20	-0.78749999E-01	0.36874358E 00	0.13597183E 00	0.31604944E 00	0.99887248E-01	0.38965657E 01	0.95412818E 00
21	-0.75000000E-01	0.51023051E 00	0.26033518E 00	0.43731762E 00	0.19124671E 00	0.35342999E 01	0.92826949E 00
22	-0.71250000E-01	0.60794937E 00	0.36960243E 00	0.52107228E 00	0.27151632E 00	0.31897057E 01	0.89155747E 00
23	-0.67500000E-01	0.64024054E 00	0.40990795E 00	0.54874898E 00	0.30112544E 00	0.28627830E 01	0.85084196E 00
24	-0.63750000E-01	0.59272718E 00	0.35132551E 00	0.50802537E 00	0.25808977E 00	0.25535317E 01	0.81594536E 00
25	-0.60000000E-01	0.46132719E 00	0.21282278E 00	0.39540268E 00	0.15634328E 00	0.22619520E 01	0.79480601E 00
26	-0.56250000E-01	0.25389001E 00	0.64460138E-01	0.21760866E 00	0.47353528E-01	0.19880437E 01	0.78840329E 00
27	-0.52500000E-01	0.98951941E-02	0.97914864E-04	0.84811525E-02	0.71929946E-04	-0.14097865E 01	0.78839356E 00
28	-0.48750000E-01	0.30041629E 00	0.90249946E-01	0.25748625E 00	0.66299166E-01	-0.16483509E 01	0.77942917E 00
29	-0.45000000E-01	0.58169372E 00	0.33836758E 00	0.49856861E 00	0.24857065E 00	-0.18692447E 01	0.74581966E 00
30	-0.41250000E-01	0.81612231E 00	0.66605562E 00	0.69949692E 00	0.489[illegible]593E 00	-0.20724669E 01	0.67966142E 00
31	-0.37500000E-01	0.96974169E 00	0.94039896E 00	0.83116381E 00	0.69083328E 00	-0.22580177E 01	0.58625308E 00
32	-0.33750000E-01	0.10172667E 01	0.10348316E 01	0.87189743E 00	0.76020512E 00	0.38572884E 01	0.48346489E 00
33	-0.30000000E-01	0.94611520E 00	0.89513396E 00	0.81091358E 00	0.65758083E 00	0.37070806E 01	0.39455266E 00
34	-0.26250000E-01	0.75879315E 00	0.57576705E 00	0.65036020E 00	0.42296839E 00	0.35745444E 01	0.33736263E 00
35	-0.22500000E-01	0.47322426E 00	0.22394120E 00	0.40559963E 00	0.16451106E 00	0.34596796E 01	0.31511891E 00
36	-0.18750000E-01	0.12090488E 00	0.14617989E-01	0.10362735E 00	0.10738627E-01	0.33624864E 01	0.31366692E 00
37	-0.15000000E-01	0.25691208E 00	0.66003815E-01	0.22019887E 00	0.48487540E-01	0.14137199E 00	0.30711087E 00
38	-0.11250000E-01	0.61450456E 00	0.37761585E 00	0.52669072E 00	0.27740311E 00	0.79521738E-01	0.26960288E 00
39	-0.75000000E-02	0.90771194E 00	0.82394096E 00	0.77799822E 00	0.60528122E 00	0.35342991E-01	0.18776214E 00
40	-0.37500000E-02	0.10998590E 01	0.12096899E 01	0.94268715E 00	0.88865905E 00	0.88357478E-02	0.67605552E-01
41	0.	0.11667275E 01	0.13612531E 01	0.10000000E 01	0.10000000E 01	0.	0.67605564E-01
42	0.37500000E-02	0.10998590E 01	0.12096899E 01	0.94268715E 00	0.88865905E 00	0.88357478E-02	0.18776214E 00
43	0.75000000E-02	0.90771195E 00	0.82394097E 00	0.77799822E 00	0.60528123E 00	0.35342991E-01	0.26960289E 00
44	0.11250000E-01	0.61450457E 00	0.37761586E 00	0.52669073E 00	0.27740312E 00	0.79521775E-01	0.30711087E 00
45	0.15000000E-01	0.25691208E 00	0.66003816E-01	0.22019887E 00	0.48487540E-01	0.14137199E 00	0.31366692E 00
46	0.18750000E-01	0.12090488E 00	0.14617991E-01	0.10362735E 00	0.10738628E-01	0.33624864E 01	0.31511891E 00
47	0.22500000E-01	0.47322426E 00	0.22394120E 00	0.40559963E 00	0.16451106E 00	0.34596797E 01	0.33736264E 00
48	0.26250000E-01	0.75879316E 00	0.57576706E 00	0.65036021E 00	0.42296840E 00	0.35745444E 01	0.39455266E 00
49	0.30000000E-01	0.94611518E 00	0.89513393E 00	0.81091357E 00	0.65758081E 00	0.37070806E 01	0.48346490E 00
50	0.33750000E-01	0.10172667E 01	0.10348316E 01	0.87189742E 00	0.76020510E 00	0.38572884E 01	0.58625308E 00

FAR FIELD RESULTS

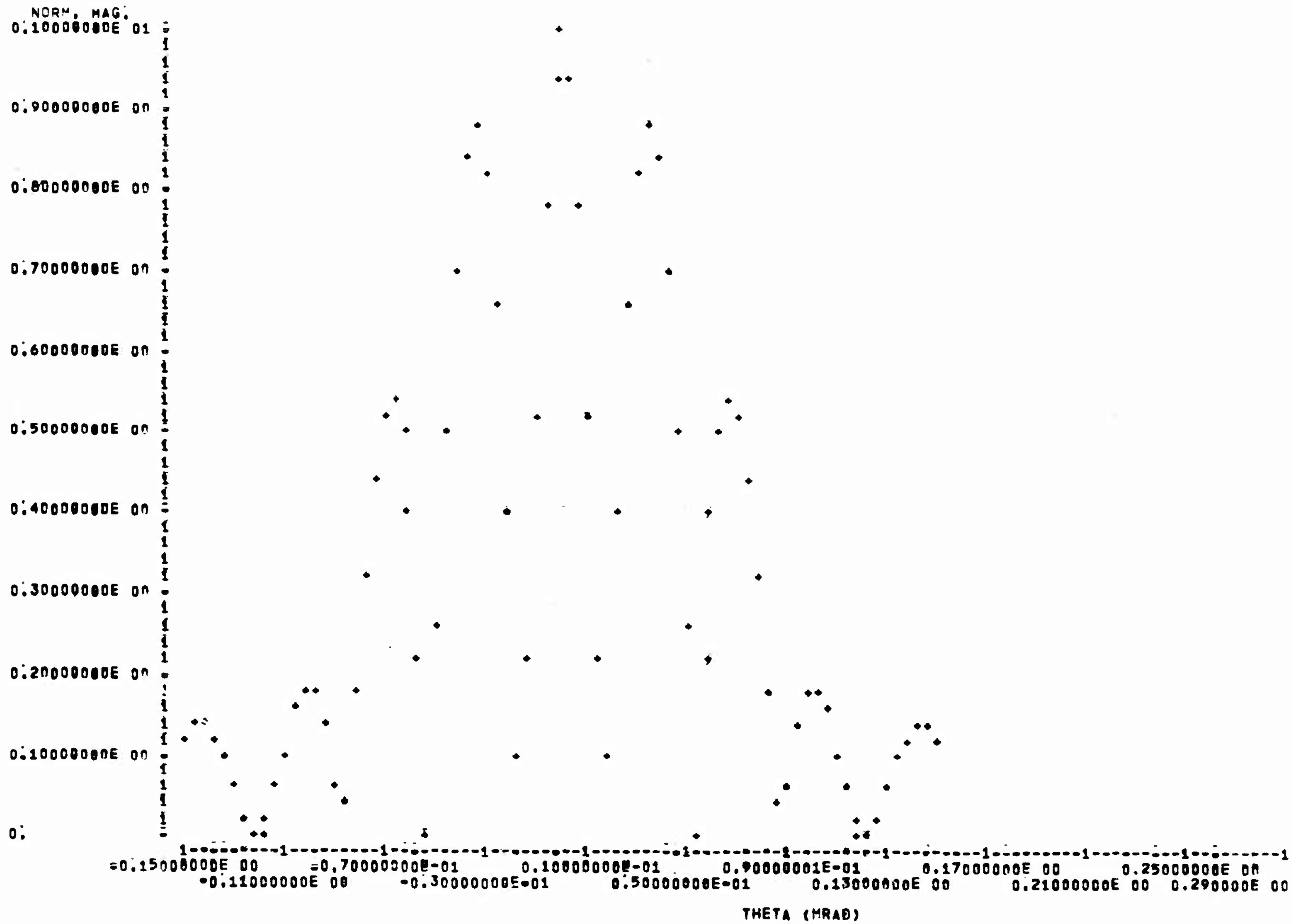
I	THETA (MRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
51	0.37500000E-01	0.96974169E 00	0.94039896E 00	0.83116381E 00	0.69083328E 00	-0.22580177E 01	0.67966142E 00
52	0.41250000E-01	0.81612232E 00	0.66605565E 00	0.69949693E 00	0.48929596E 00	-0.20724669E 01	0.74581967E 00
53	0.45000000E-01	0.58169371E 00	0.33836757E 00	0.49856860E 00	0.24857065E 00	-0.18692447E 01	0.77942918E 00
54	0.48750000E-01	0.30041629E 00	0.90249949E-01	0.29748625E 00	0.66299167E-01	-0.16483509E 01	0.78839357E 00
55	0.52500000E-01	0.98951926E-02	0.97914837E-04	0.84811512E-02	0.71929926E-04	-0.14097866E 01	0.78840330E 00
56	0.56250000E-01	0.25389001E 00	0.64460139E-01	0.21760866E 00	0.47353528E-01	0.19880438E 01	0.79480602E 00
57	0.60000000E-01	0.46132717E 00	0.21282278E 00	0.39540268E 00	0.15634328E 00	0.22619520E 01	0.81594536E 00
58	0.63750000E-01	0.59272718E 00	0.35132551E 00	0.50802537E 00	0.25808977E 00	0.25535317E 01	0.85084196E 00
59	0.67500000E-01	0.64024054E 00	0.40990795E 00	0.54874898E 00	0.30112544E 00	0.28627830E 01	0.89155748E 00
60	0.71250000E-01	0.60794936E 00	0.36960242E 00	0.52107227E 00	0.27151631E 00	0.31897057E 01	0.92826951E 00
61	0.75000000E-01	0.51023050E 00	0.26033517E 00	0.43731762E 00	0.19124670E 00	0.35342999E 01	0.95412818E 00
62	0.78749999E-01	0.36874358E 00	0.13597183E 00	0.31604944E 00	0.99887248E-01	0.38965657E 01	0.96763405E 00
63	0.82500000E-01	0.20858594E 00	0.43508096E-01	0.17877863E 00	0.31961797E-01	-0.20066824E 01	0.97195563E 00
64	0.86250000E-01	0.54254981E-01	0.29436029E-02	0.46501843E-01	0.21624214E-02	-0.16090736E 01	0.97224801E 00
65	0.90000000E-01	0.73950359E-01	0.54686556E-02	0.63382715E-01	0.40173686E-02	0.19477994E 01	0.97279119E 00
66	0.93750000E-01	0.16256248E 00	0.26426561E-01	0.13933200E 00	0.19413407E-01	0.23807511E 01	0.97541610E 00
67	0.97500000E-01	0.20627031E 00	0.42547440E-01	0.17679390E 00	0.31256082E-01	0.28313743E 01	0.97964228E 00
68	0.10125000E 00	0.20782314E 00	0.43190458E-01	0.17812483E 00	0.31728455E-01	0.32996690E 01	0.98393232E 00
69	0.10500000E 00	0.17663474E 00	0.31199833E-01	0.15139331E 00	0.22919935E-01	0.37856351E 01	0.98703136E 00
70	0.10875000E 00	0.12641162E 00	0.15979898E-01	0.10834717E 00	0.11739109E-01	-0.19939125E 01	0.98861863E 00
71	0.11250000E 00	0.72269197E-01	0.52228368E-02	0.61941795E-01	0.38367859E-02	-0.14726033E 01	0.98913740E 00
72	0.11625000E 00	0.27855416E-01	0.77592421E-03	0.23874826E-01	0.57000729E-03	-0.93362276E 00	0.98921446E 00
73	0.12000000E 00	0.29687863E-02	0.88136920E-05	0.25445412E-02	0.64746900E-05	-0.37697406E 00	0.98921534E 00
74	0.12375000E 00	0.20460410E-02	0.41862835E-05	0.17536579E-02	0.30753160E-05	0.19734923E 00	0.98921576E 00
75	0.12750000E 00	0.23726005E-01	0.56292333E-03	0.20335915E-01	0.41353318E-03	0.78934873E 00	0.98927168E 00
76	0.13125000E 00	0.61500769E-01	0.37823445E-02	0.52712195E-01	0.27785755E-02	0.13990157E 01	0.98964736E 00
77	0.13500000E 00	0.10527840E 00	0.11083542E-01	0.90233923E-01	0.81421607E-02	0.20263540E 01	0.99074828E 00
78	0.13875000E 00	0.14353221E 00	0.20601494E-01	0.12302119E 00	0.15134212E-01	0.26713639E 01	0.99279460E 00
79	0.14250000E 00	0.16562559E 00	0.27431835E-01	0.14195738E 00	0.20151898E-01	0.33340451E 01	0.99551935E 00
80	0.14625000E 00	0.16388962E 00	0.26859807E-01	0.14046949E 00	0.19731677E-01	-0.22687875E 01	0.99818728E 00
81	0.15000000E 00	0.13509147E 00	0.18249705E-01	0.11578865E 00	0.13406547E-01	-0.19707632E 01	0.10000000E 01


FAR FIELD RESULTS
NUMBER OF POINTS= 81
X INCREMENT= 0.27272727E-02
Y INCREMENT= 0.23293630E-01
MAGNITUDE
0.11667275E 01
0.10502594E 01
0.93379124E 00
0.81732309E 00
0.70085493E 00
0.58438679E 00
0.46791864E 00
0.35145049E 00
0.23498234E 00
0.11851419E 00
0.20460410E-02
-0.15000000E 00
-0.12272727E 00
-0.95454546E-01
-0.68181818E-01
-0.40909091E-01
-0.13636364E-01
0.13636364E-01
0.40909091E-01
0.68181818E-01
0.95454546E-01
0.12272727E 00
0.150000E 00
THETA (MRAD)

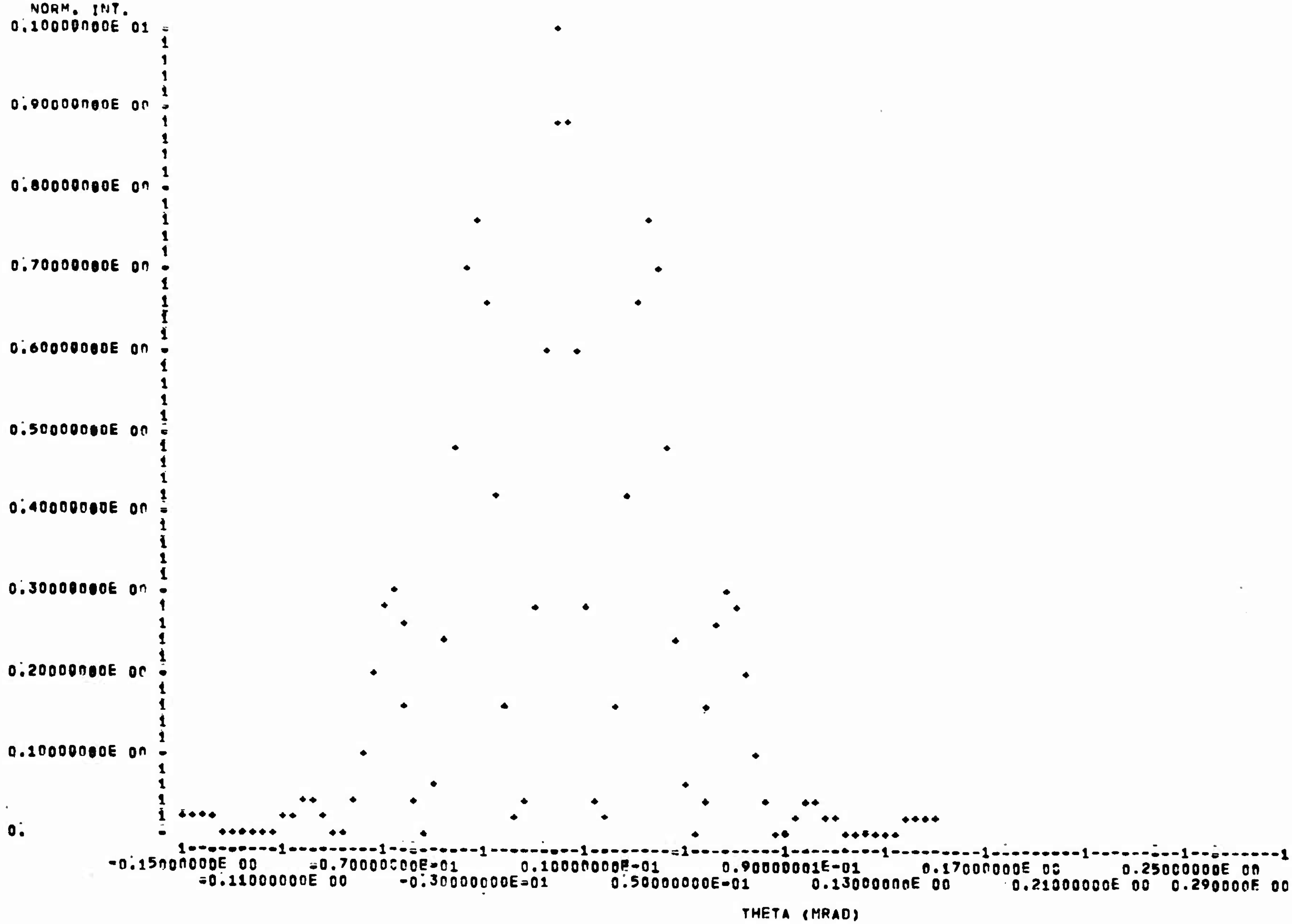
FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.27272727E-02 Y INCREMENT= 0.27224979E-01



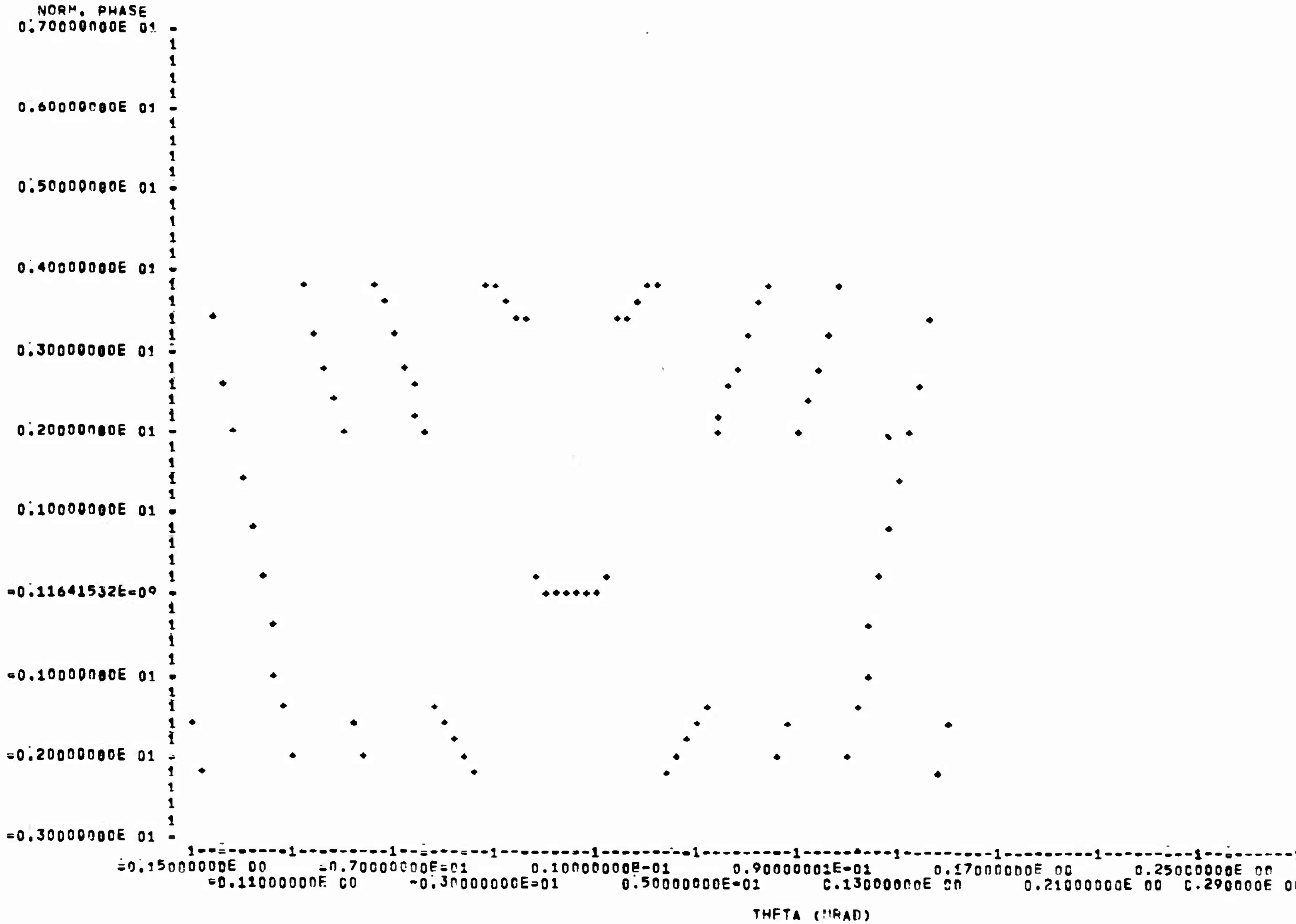
FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.40000000E-02 Y INCREMENT= 0.20000000E-01

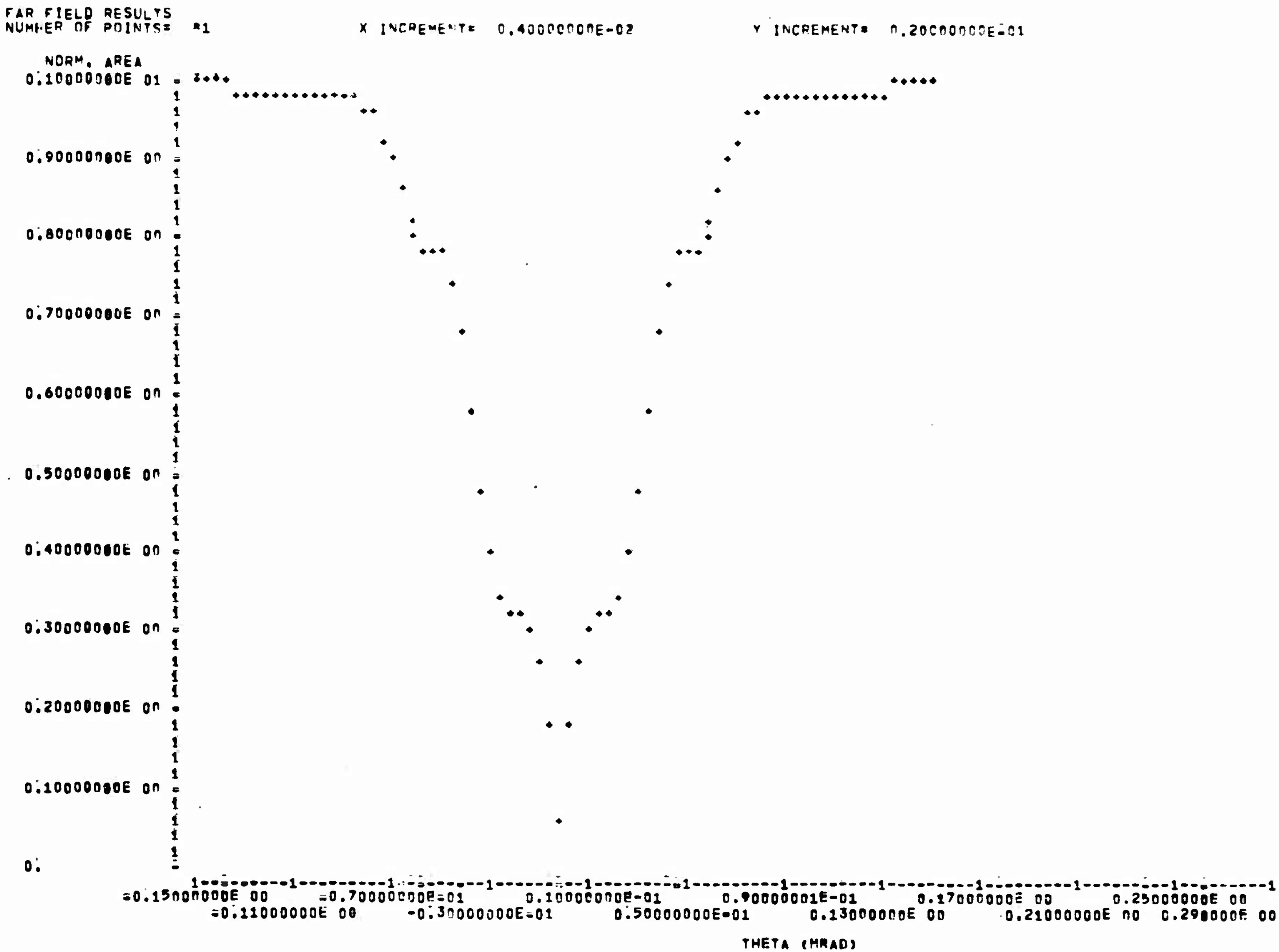


FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.40000000E-02 Y INCREMENT= 0.20000000E-01



FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.40000000E-02 Y INCREMENT= 0.20000000E 00





FAR FIELD RESULTS
NUMBER OF POINTS= 81
X INCREMENT= 0.40000000E-02
Y INCREMENT= 0.20000000E-01
NORM. AREA
0.10000000E 01
0.90000000E 00
0.80000000E 00
0.70000000E 00
0.60000000E 00
0.50000000E 00
0.40000000E 00
0.30000000E 00
0.20000000E 00
0.10000000E 00
0.
-0.15000000E 00
-0.11000000E 00
-0.70000000E-01
-0.30000000E-01
0.10000000E-01
0.50000000E-01
0.90000001E-01
0.13000000E 00
0.17000000E 00
0.21000000E 00
0.25000000E 00
0.29000000E 00
THETA (MRAD)

```
FAR FIELD POWER
        WAVE NUMBER  1          0.4530426E 01
```

```
USING RESTART TAPE, FILE CODE   10, TO MATCH      1

     TAPE IDENTIFICATION
         TIME      1728
         DATE      110973
         SNUMB     MC456
         PROGRAM   PR51
         CASE         8.5

GOVERNING PARAMETERS FOR TAPE INFORMATION
    NX=   81
    NZ=   18
    IWAVE=    1
    NWAVES=    1
```

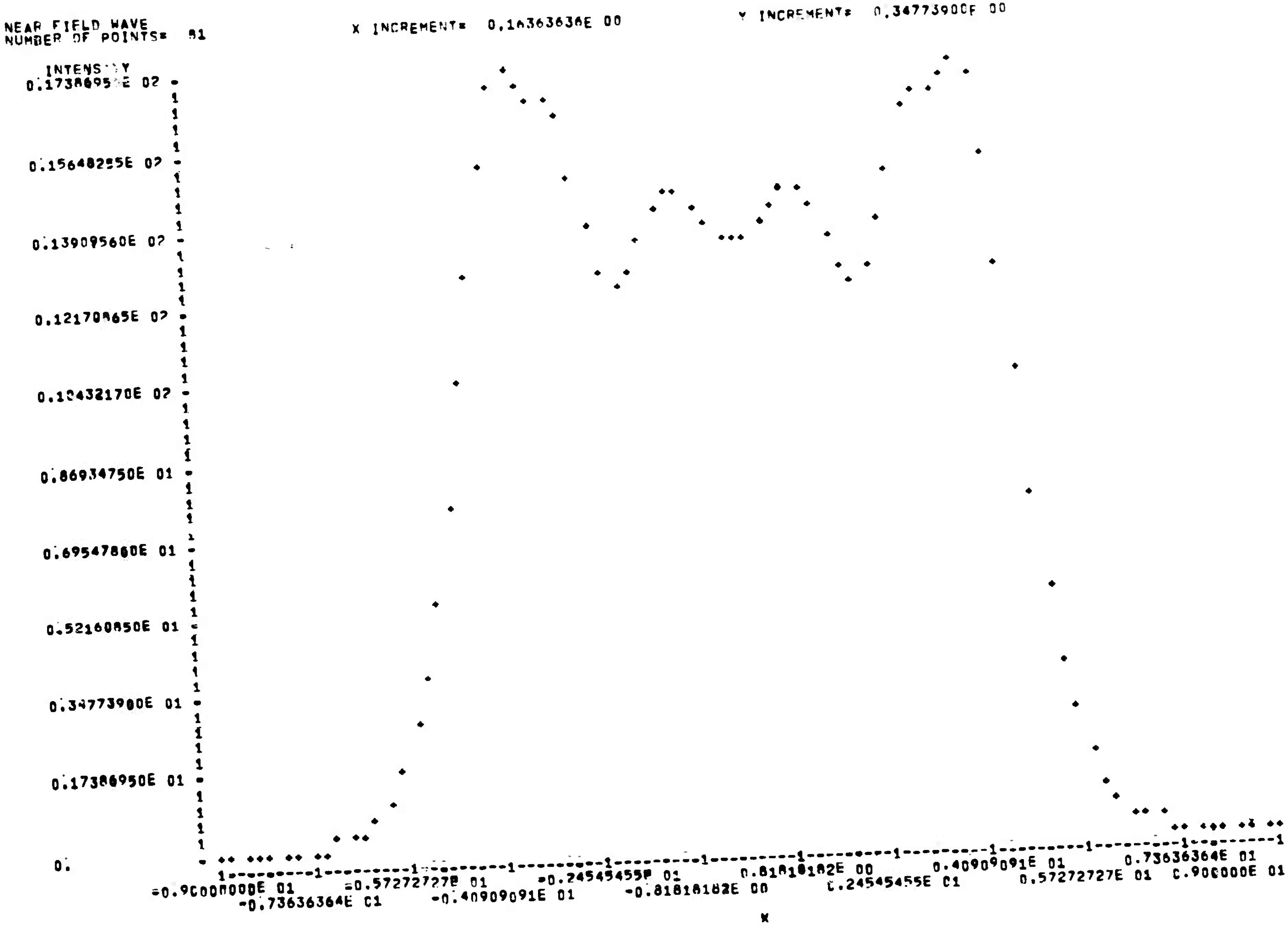
STARTING PASS 1

NEAR FIELD WAVE

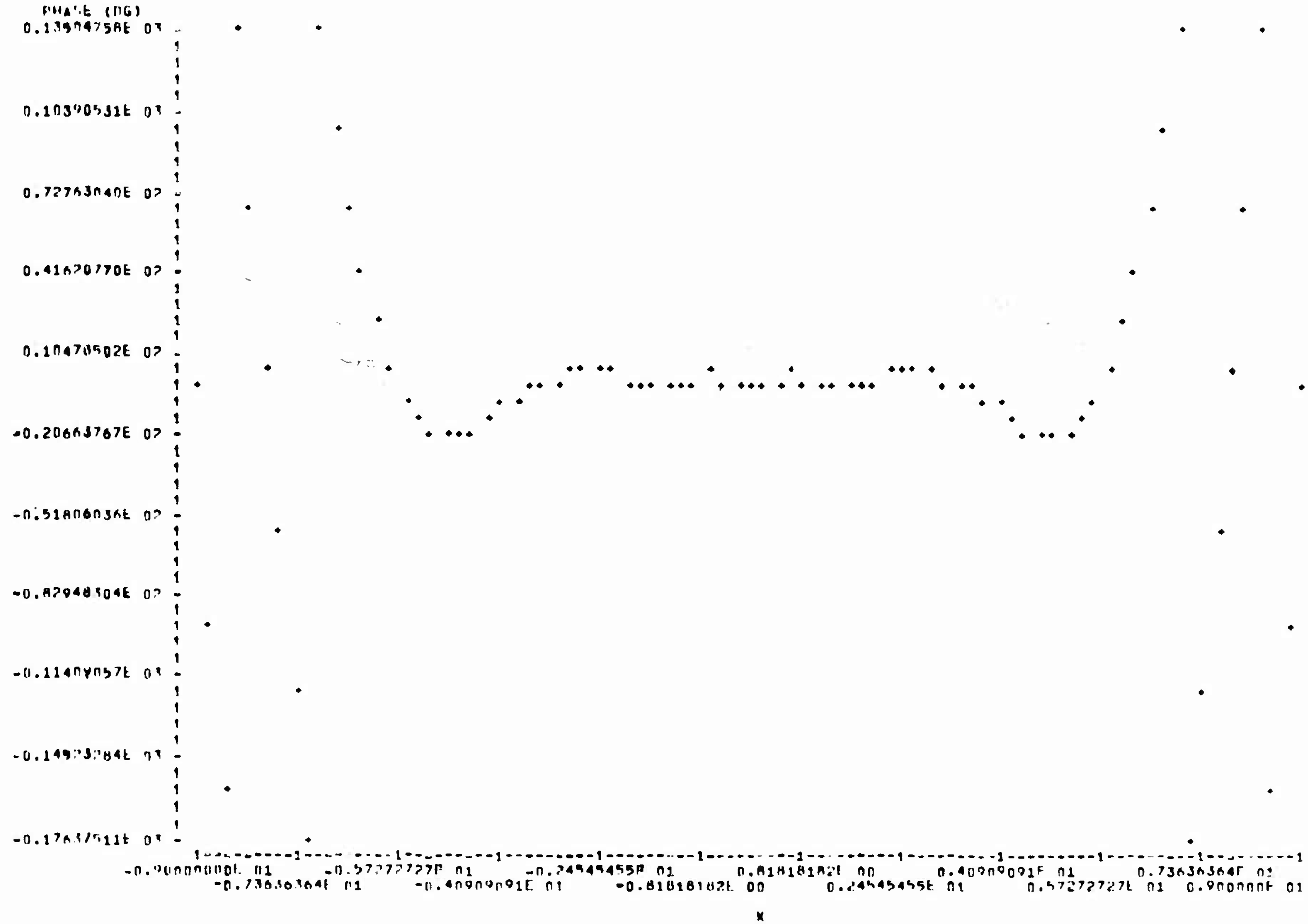
I	X	INTENSITY	PHASE (DG)
1	-0.90000000E 01	0.	-0.50000000E 00
2	-0.87750000E 01	0.75674660E-05	-0.97506783E 02
3	-0.85500000E 01	0.41665491E-04	-0.16015575E 03
4	-0.83249999E 01	0.24518104E-03	0.13211626E 03
5	-0.81000000E 01	0.12512085E-02	0.66593565E 02
6	-0.78750000E 01	0.53955163E-02	0.22078894E 01
7	-0.76500000E 01	0.19177114E-01	-0.60500175E 02
8	-0.74250000E 01	0.54341917E-01	-0.12060474E 03
9	-0.72000000E 01	0.11943601E 00	-0.17637511E 03
10	-0.69750000E 01	0.20487260E 00	0.13504758E 03
11	-0.67500000E 01	0.30463679E 00	0.96663246E 02
12	-0.65250000E 01	0.47058502E 00	0.67128470E 02
13	-0.63000000E 01	0.75140557E 00	0.41738200E 02
14	-0.60750000E 01	0.11381766E 01	0.21065556E 02
15	-0.58500000E 01	0.17311248E 01	0.56140589E 01
16	-0.56250000E 01	0.26115426E 01	-0.63136734E 01
17	-0.54000000E 01	0.38408426E 01	-0.14382819E 02
18	-0.51750000E 01	0.55497097E 01	-0.19239547E 02
19	-0.49500000E 01	0.77306541E 01	-0.21249061E 02
20	-0.47250000E 01	0.10302654E 02	-0.20634401E 02
21	-0.45000000E 01	0.13012202E 02	-0.18087313E 02
22	-0.42750000E 01	0.15405082E 02	-0.13932439E 02
23	-0.40500000E 01	0.16915964E 02	-0.94520355E 01
24	-0.38250000E 01	0.17386950E 02	-0.51728818E 01
25	-0.36000000E 01	0.16899323E 02	-0.25051325E 01
26	-0.33750000E 01	0.16613077E 02	-0.14853200E 01
27	-0.31500000E 01	0.16824183E 02	0.47121676E 00
28	-0.29250000E 01	0.16351832E 02	0.30857758E 01
29	-0.27000000E 01	0.15078270E 02	0.44063043E 01
30	-0.24750000E 01	0.13803747E 02	0.41645535E 01
31	-0.22500000E 01	0.12890086E 02	0.27963634E 01
32	-0.20250000E 01	0.12502281E 02	0.77025557E 00
33	-0.18000000E 01	0.12717130E 02	-0.11165999E 01
34	-0.15750000E 01	0.13466974E 02	-0.21954015E 01
35	-0.13500000E 01	0.14306391E 02	-0.21524707E 01
36	-0.11250000E 01	0.14681104E 02	-0.11449752E 01
37	-0.90000000E 00	0.14606437E 02	0.55489418E 00
38	-0.67500000E 00	0.14365512E 02	0.16909650E 01
39	-0.45000000E 00	0.14048664E 02	0.99090094E 00
40	-0.22500000E 00	0.13641351E 02	-0.56461575E 00
41	0.	0.13414623E 02	-0.12733530E 01
42	0.22500000E 00	0.13641351E 02	-0.56461295E 00
43	0.45000000E 00	0.14048665E 02	0.99090175E 00
44	0.67500000E 00	0.14365513E 02	0.16909655E 01
45	0.90000000E 00	0.14606438E 02	0.55489293E 00
46	0.11250000E 01	0.14681105E 02	-0.11449748E 01
47	0.13500000E 01	0.14306392E 02	-0.21524732E 01
48	0.15750000E 01	0.13466972E 02	-0.21954028E 01
49	0.18000000E 01	0.12717129E 02	-0.11165989E 01
50	0.20250000E 01	0.12502280E 02	0.77025545E 00

NEAR FIELD WAVE

I	Y	INTENSITY	PHASE (DG)
51	0.22500000E 01	0.12890086E 02	0.27963623E 01
52	0.24750000E 01	0.13803747E 02	0.41645535E 01
53	0.27000000E 01	0.15078271E 02	0.44063069E 01
54	0.29250000E 01	0.16351832E 02	0.30857753E 01
55	0.31500000E 01	0.16824184E 02	0.47121233E 00
56	0.33750000E 01	0.16613077E 02	-0.14853186E 01
57	0.36000000E 01	0.16899323E 02	-0.25051346E 01
58	0.38250000E 01	0.17386949E 02	-0.51728802E 01
59	0.40500000E 01	0.16915964E 02	-0.94520372E 01
60	0.42750000E 01	0.15405081E 02	-0.13932439E 02
61	0.45000000E 01	0.13012202E 02	-0.18087312E 02
62	0.47250000E 01	0.10302654E 02	-0.20634401E 02
63	0.49500000E 01	0.77306541E 01	-0.21249058E 02
64	0.51750000E 01	0.55497094E 01	-0.19239545E 02
65	0.54000000E 01	0.38408428E 01	-0.14382815E 02
66	0.56250000E 01	0.26115426E 01	-0.63136737E 01
67	0.58500000E 01	0.17311249E 01	0.56140631E 01
68	0.60750000E 01	0.11381765E 01	0.21065558E 02
69	0.63000000E 01	0.75140547E 00	0.41738199E 02
70	0.65250000E 01	0.47058503E 00	0.67128470E 02
71	0.67500000E 01	0.30463677E 00	0.96663245E 02
72	0.69750000E 01	0.20487262E 00	0.13504757E 03
73	0.72000000E 01	0.11943605E 00	-0.17637511E 03
74	0.74250000E 01	0.54341938E-01	-0.12060474E 03
75	0.76500000E 01	0.19177119E-01	-0.60500164E 02
76	0.78750000E 01	0.53995167E-02	0.22079027E 01
77	0.81000000E 01	0.12512082E-02	0.66593578E 02
78	0.83249999E 01	0.24518096E-03	0.13211627E 03
79	0.85500000E 01	0.41665472E-04	-0.16015574E 03
80	0.87750000E 01	0.75674633E-05	-0.97506788E 02
61	0.90000000E 01	0.	-0.50000000E 00


NEAR FIELD WAVE
NUMBER OF POINTS= 81
X INCREMENT= 0.16363636E 00
Y INCREMENT= 0.34773900E 00
INTENSITY
0.17386950E 02
0.15648255E 02
0.13909560E 02
0.12170865E 02
0.10432170E 02
0.86934750E 01
0.69547800E 01
0.52160850E 01
0.34773900E 01
0.17386950E 01
0.
-0.90000000E 01
-0.73636364E 01
-0.57272727E 01
-0.40909091E 01
-0.24545455E 01
-0.81818182E 00
0.81818182E 00
0.24545455E 01
0.40909091E 01
0.57272727E 01
0.73636364E 01
0.90000000E 01
X

NEAR FIELD WAVE
NUMBER OF POINTS= 81   X INCREMENT= 0.16363636E 00   Y INCREMENT= 0.62284538E 01



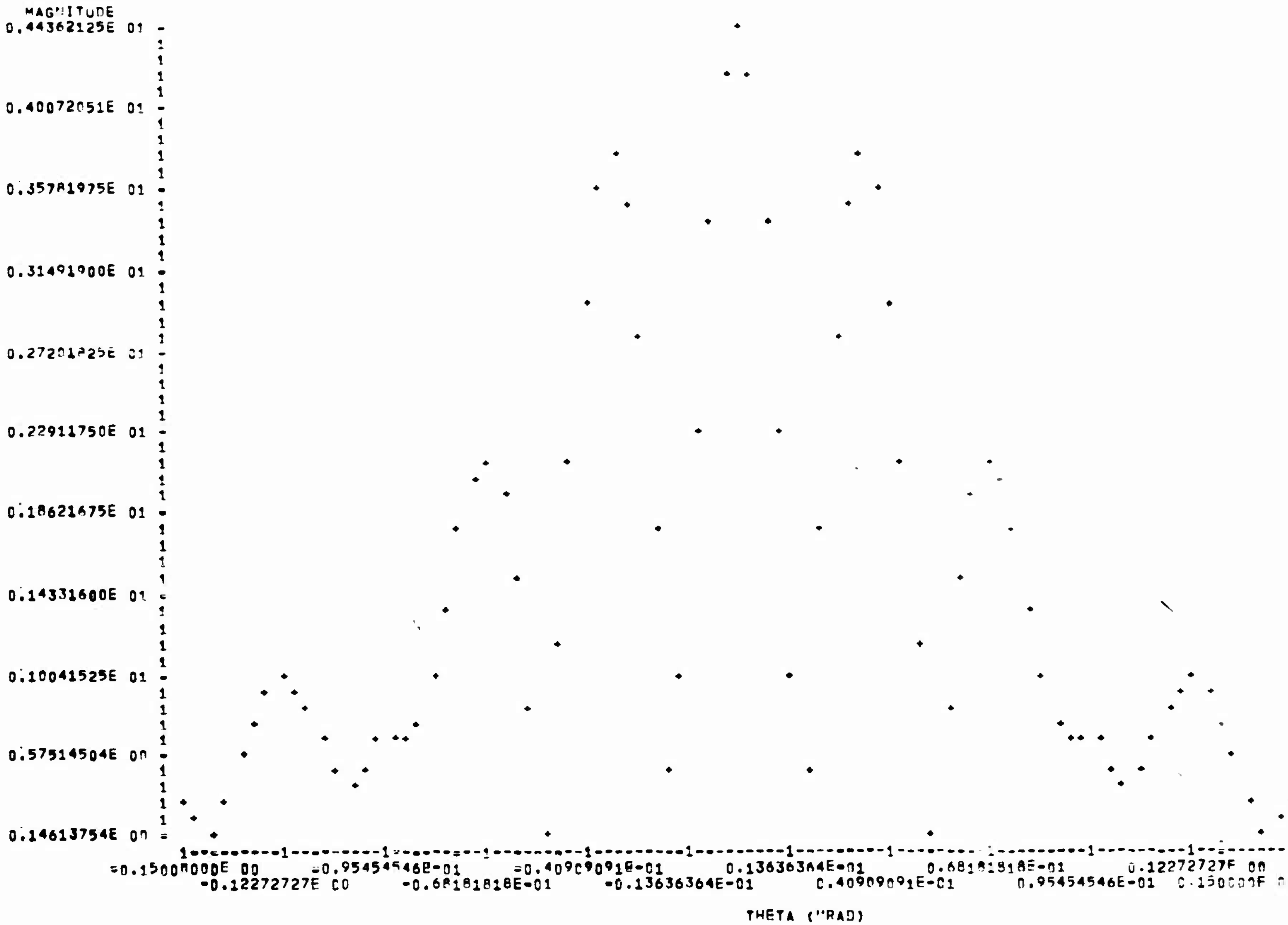
FAR FIELD RESULTS

I	THETA (MRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
1	-0.15000000E 00	0.33093774E 00	0.10951979E 00	0.74599164E-01	0.55650351E-02	0.19918697E 01	0.99922224E 00
2	-0.14625000E 00	0.19425066E 00	0.37733321E-01	0.43787502E-01	0.19173453E-02	0.17819729E 01	0.99895428E 00
3	-0.14250000E 00	0.16415078E 00	0.26945479E-01	0.37002461E-01	0.13691821E-02	0.24760834E 01	0.99876293E 00
4	-0.13875000E 00	0.35155381E 00	0.12359008E 00	0.79246386E-01	0.62799897E-02	0.25559837E 01	0.99788525E 00
5	-0.13500000E 00	0.57899822E 00	0.33523894E 00	0.13051634E 00	0.17034519E-01	0.21814877E 01	0.99550455E 00
6	-0.13125000E 00	0.78319605E 00	0.61339605E 00	0.17654611E 00	0.31168527E-01	0.17139000E 01	0.99114852E 00
7	-0.12750000E 00	0.92927430E 00	0.86355072E 00	0.20947470E 00	0.43879651E-01	0.12157485E 01	0.98501600E 00
8	-0.12375000E 00	0.99226984E 00	0.98459943E 00	0.22367900E 00	0.50030505E-01	0.69958422E 00	0.97802386E 00
9	-0.12000000E 00	0.95996507E 00	0.92153292E 00	0.21639294E 00	0.46825903E-01	0.16121528E 00	0.97147959E 00
10	-0.11625000E 00	0.83788673E 00	0.70205417E 00	0.18887434E 00	0.35673518E-01	-0.41921838E 00	0.96649395E 00
11	-0.11250000E 00	0.65616505E 00	0.43055258E 00	0.14791109E 00	0.21877692E-01	-0.10927435E 01	0.96343638E 00
12	-0.10875000E 00	0.48454692E 00	0.23478572E 00	0.10922536E 00	0.11930180E-01	-0.19713447E 01	0.96176904E 00
13	-0.10500000E 00	0.43803785E 00	0.19187716E 00	0.98741403E-01	0.97498647E-02	0.31972326E 01	0.96040643E 00
14	-0.10125000E 00	0.53003725E 00	0.28093949E 00	0.11947968E 00	0.14275394E-01	0.22097101E 01	0.95841134E 00
15	-0.97500000E-01	0.63367350E 00	0.40154211E 00	0.14284111E 00	0.20403582E-01	0.14350327E 01	0.95555978E 00
16	-0.93750000E-01	0.67680921E 00	0.45807071E 00	0.15256465E 00	0.23275972E-01	0.71402658E 00	0.95230679E 00
17	-0.90000000E-01	0.67825697E 00	0.46003252E 00	0.15289100E 00	0.23375658E-01	-0.82608845E-01	0.94903986E 00
18	-0.86250000E-01	0.74955662E 00	0.56183513E 00	0.16896319E 00	0.28548560E-01	-0.98360567E 00	0.94504999E 00
19	-0.82500000E-01	0.99457898E 00	0.98918734E 00	0.22419557E 00	0.50263631E-01	-0.18048123E 01	0.93802527E 00
20	-0.78749999E-01	0.13675032E 01	0.18700650E 01	0.30825917E 00	0.95023718E-01	0.38494788E 01	0.92474499E 00
21	-0.75000000E-01	0.17514218E 01	0.30674783E 01	0.39480114E 00	0.15586794E 00	0.33603359E 01	0.90296127E 00
22	-0.71250000E-01	0.20355103E 01	0.41433022E 01	0.45883967E 00	0.21053384E 00	0.29543424E 01	0.87353759E 00
23	-0.67500000E-01	0.21284361E 01	0.45302404E 01	0.47978678E 00	0.23019536E 00	0.26003437E 01	0.84136605E 00
24	-0.63750000E-01	0.19661412E 01	0.38657114E 01	0.44320267E 00	0.19642861E 00	0.22810405E 01	0.81391368E 00
25	-0.60000000E-01	0.15211123E 01	0.23137825E 01	0.34288935E 00	0.11757036E 00	0.19827520E 01	0.79748233E 00
26	-0.56250000E-01	0.80995850E 00	0.65603278E 00	0.18257883E 00	0.33335038E-01	0.16718065E 01	0.79282352E 00
27	-0.52500000E-01	0.14613756E 00	0.21355187E-01	0.32941966E-01	0.10851731E-02	-0.94726054E 00	0.79267185E 00
28	-0.48750000E-01	0.11498705E 01	0.13222023E 01	0.25920096E 00	0.67185136E-01	-0.17381988E 01	0.78328223E 00
29	-0.45000000E-01	0.21603037E 01	0.46669119E 01	0.48697028E 00	0.23714005E 00	-0.19730358E 01	0.75014012E 00
30	-0.41250000E-01	0.30159408E 01	0.90958990E 01	0.67984588E 00	0.46219042E 00	-0.21657516E 01	0.68554553E 00
31	-0.37500000E-01	0.35872828E 01	0.12868598E 02	0.80863637E 00	0.65389277E 00	0.39486472E 01	0.59415910E 00
32	-0.33750000E-01	0.37743265E 01	0.14245540E 02	0.85079929E 00	0.72385944E 00	0.37997386E 01	0.49299431E 00
33	-0.30000000E-01	0.35228268E 01	0.12410309E 02	0.79410686E 00	0.63060578E 00	0.36696704E 01	0.40486242E 00
34	-0.26250000E-01	0.28350932E 01	0.80377536E 01	0.63907967E 00	0.40842282E 00	0.35593768E 01	0.34778226E 00
35	-0.22500000E-01	0.17730789E 01	0.31438089E 01	0.39968304E 00	0.15974654E 00	0.34755690E 01	0.32545648E 00
36	-0.18750000E-01	0.45579103E 00	0.20774547E 00	0.10274328E 00	0.10556182E-01	0.35148049E 01	0.32398117E 00
37	-0.15000000E-01	0.97954626E 00	0.95951087E 00	0.22080688E 00	0.48755679E-01	0.61861813E-01	0.31716720E 00
38	-0.11250000E-01	0.23337833E 01	0.54465446E 01	0.52607563E 00	0.27675558E 00	0.53169638E-01	0.27848853E 00
39	-0.75000000E-02	0.34487616E 01	0.11893957E 02	0.77741127E 00	0.60436828E 00	0.25551416E-01	0.19402352E 00
40	-0.37500000E-02	0.41810844E 01	0.17481467E 02	0.94248965E 00	0.88828672E 00	0.65647960E-02	0.69878770E-01
41	0.	0.44362125E 01	0.19679982E 02	0.10000000E 01	0.10000008E 01	0.	0.69878743E-01
42	0.37500000E-02	0.41810845E 01	0.17481467E 02	0.94248966E 00	0.88828679E 00	0.65647960E-02	0.19402349E 00
43	0.75000000E-02	0.34487616E 01	0.11893957E 02	0.77741127E 00	0.60436828E 00	0.25551423E-01	0.27848850E 00
44	0.11250000E-01	0.23337834E 01	0.54465448E 01	0.52607564E 00	0.27675558E 00	0.53169638E-01	0.31716717E 00
45	0.15000000E-01	0.97954623E 00	0.95951083E 00	0.22080688E 00	0.48755676E-01	0.61861858E-01	0.32398115E 00
46	0.18750000E-01	0.45579103E 00	0.20774546E 00	0.10274328E 00	0.10556182E-01	0.35148050E 01	0.32545644E 00
47	0.22500000E-01	0.17730789E 01	0.31438088E 01	0.39968304E 00	0.15974653E 00	0.34755690E 01	0.34778222E 00
48	0.26250000E-01	0.28350933E 01	0.80377539E 01	0.63907968E 00	0.40842284E 00	0.35593768E 01	0.40486238E 00
49	0.30000000E-01	0.35228268E 01	0.12410309E 02	0.79410686E 00	0.63060571E 00	0.36696704E 01	0.49299427E 00
50	0.33750000E-01	0.37743265E 01	0.14245541E 02	0.85079930E 00	0.72385944E 00	0.37997386E 01	0.59415907E 00

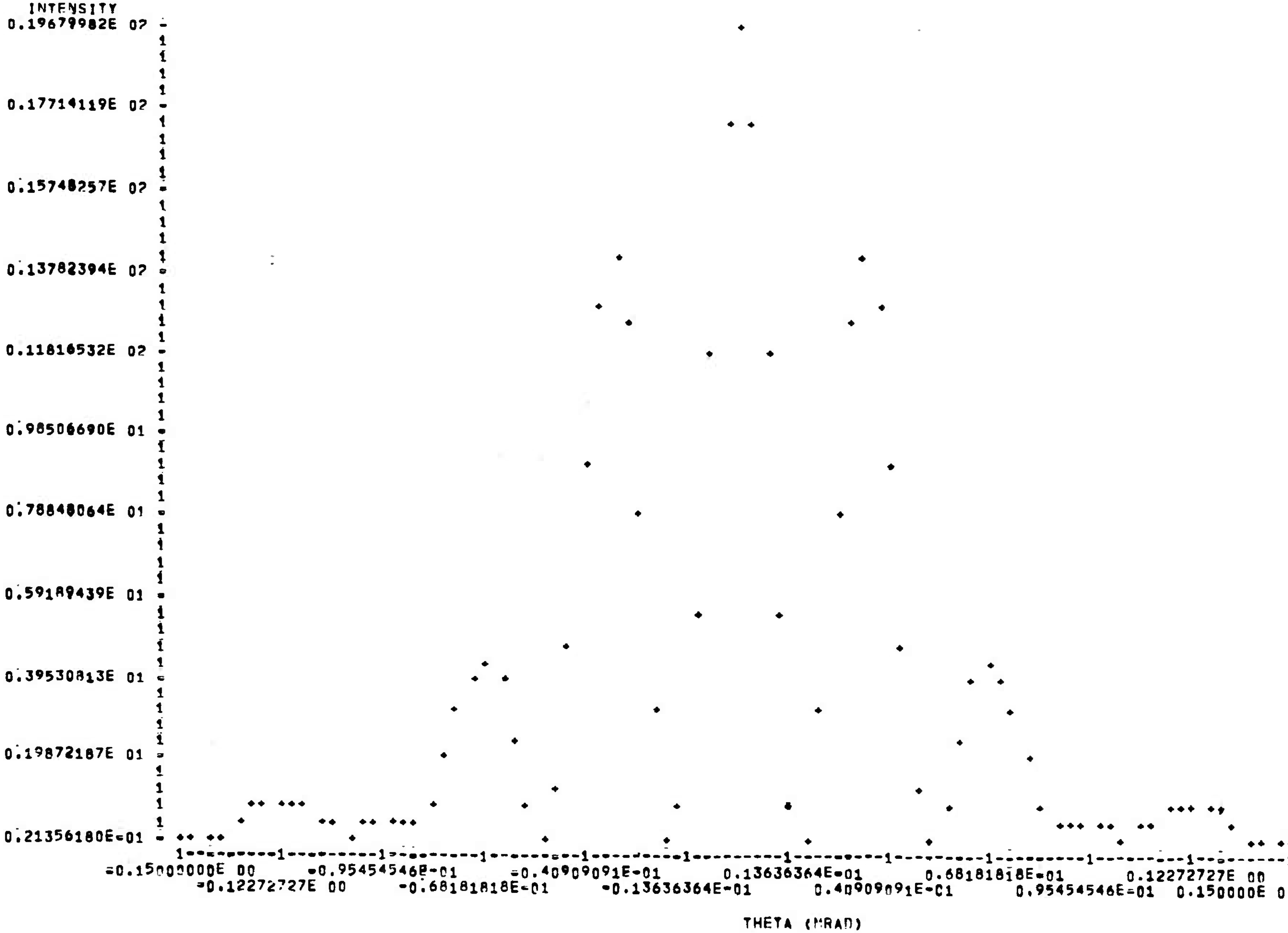
FAR FIELD RESULTS

I	THETA (MRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
51	0.37500000E-01	0.35872829E 01	0.12868599E 02	0.88863640E 00	0.65389282E 00	0.39486472E 01	0.68554550E 00
52	0.41250000E-01	0.30159409E 01	0.90958995E 01	0.67984590E 00	0.46219044E 00	-0.21657516E 01	0.75014009E 00
53	0.45000000E-01	0.21603037E 01	0.46669120E 01	0.48697028E 00	0.23714006E 00	-0.19730358E 01	0.78328221E 00
54	0.48750000E-01	0.11498706E 01	0.13222023E 01	0.25920096E 00	0.67185139E-01	-0.17381988E 01	0.79267184E 00
55	0.52500000E-01	0.14613754E 00	0.21356180E-01	0.32941961E-01	0.10851728E-02	-0.94726080E 00	0.79282350E 00
56	0.56250000E-01	0.80995851E 00	0.65603279E 00	0.18257883E 00	0.33335030E-01	0.16718065E 01	0.79748232E 00
57	0.60000000E-01	0.15211123E 01	0.23137827E 01	0.34288535E 00	0.11757037E 00	0.19827520E 01	0.81391365E 00
58	0.63750000E-01	0.19661412E 01	0.38657113E 01	0.44320267E 00	0.19642860E 00	0.22810405E 01	0.84136602E 00
59	0.67500000E-01	0.21284362E 01	0.45302405E 01	0.47978679E 00	0.23019536E 00	0.26003437E 01	0.87353755E 00
60	0.71250000E-01	0.20355104E 01	0.41433024E 01	0.45883969E 00	0.21053386E 00	0.29543424E 01	0.90296124E 00
61	0.75000000E-01	0.17514219E 01	0.30674785E 01	0.39480116E 00	0.15586796E 00	0.33603359E 01	0.92474496E 00
62	0.78749999E-01	0.13675033E 01	0.18700652E 01	0.30825919E 00	0.95023726E-01	0.38494789E 01	0.93802523E 00
63	0.82500000E-01	0.99457898E 00	0.98918734E 00	0.22419552E 00	0.50263631E-01	-0.18048123E 01	0.94504996E 00
64	0.86250000E-01	0.74955663E 00	0.56183514E 00	0.16896319E 00	0.28548560E-01	-0.98360570E 00	0.94903985E 00
65	0.90000000E-01	0.67825697E 00	0.46003251E 00	0.15289100E 00	0.23375657E-01	-0.82606815E-01	0.95230677E 00
66	0.93750000E-01	0.67680920E 00	0.45807070E 00	0.15256465E 00	0.23275972E-01	0.71402661E 00	0.95555975E 00
67	0.97500000E-01	0.63367354E 00	0.40154216E 00	0.14284111E 00	0.20403584E-01	0.14350327E 01	0.95841131E 00
68	0.10125000E 00	0.53003728E 00	0.28093951E 00	0.11947969E 00	0.14275395E-01	0.22097101E 01	0.96040642E 00
69	0.10500000E 00	0.43803787E 00	0.19187718E 00	0.98741408E-01	0.97498656E-02	0.31972327E 01	0.96176902E 00
70	0.10875000E 00	0.48454697E 00	0.23478577E 00	0.10922537E 00	0.11930182E-01	-0.19713446E 01	0.96343636E 00
71	0.11250000E 00	0.65616511E 00	0.43055265E 00	0.14791111E 00	0.21877696E-01	-0.10927435E 01	0.96649394E 00
72	0.11625000E 00	0.83788680E 00	0.70205428E 00	0.18887436E 00	0.35673523E-01	-0.41921839E 00	0.97147957E 00
73	0.12000000E 00	0.95996511E 00	0.92153302E 00	0.21639295E 00	0.46825908E-01	0.16121531E 00	0.97802383E 00
74	0.12375000E 00	0.99226986E 00	0.98459948E 00	0.22367501E 00	0.50030508E-01	0.69958425E 00	0.98501598E 00
75	0.12750000E 00	0.92927429E 00	0.86355071E 00	0.20947470E 00	0.43879650E-01	0.12157485E 01	0.99114850E 00
76	0.13125000E 00	0.78319604E 00	0.61339603E 00	0.17654610E 00	0.31168527E-01	0.17139000E 01	0.99550454E 00
77	0.13500000E 00	0.57899821E 00	0.33523893E 00	0.13051634E 00	0.17034514E-01	0.21814878E 01	0.99788524E 00
78	0.13875000E 00	0.35155380E 00	0.12359007E 00	0.79246384E-01	0.62799893E-02	0.25555837E 01	0.99876291E 00
79	0.14250000E 00	0.16415078E 00	0.26945477E-01	0.37002460E-01	0.13691820E-02	0.24760833E 01	0.99895427E 00
80	0.14625000E 00	0.19425068E 00	0.37733328E-01	0.43787506E-01	0.19173457E-02	0.17815729E 01	0.99922224E 00
81	0.15000000E 00	0.33093776E 00	0.10951980E 00	0.74599166E-01	0.55650356E-02	0.19918698E 01	0.10000000E 01

FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.27272727E-02 Y INCREMENT= 0.85801500E-01



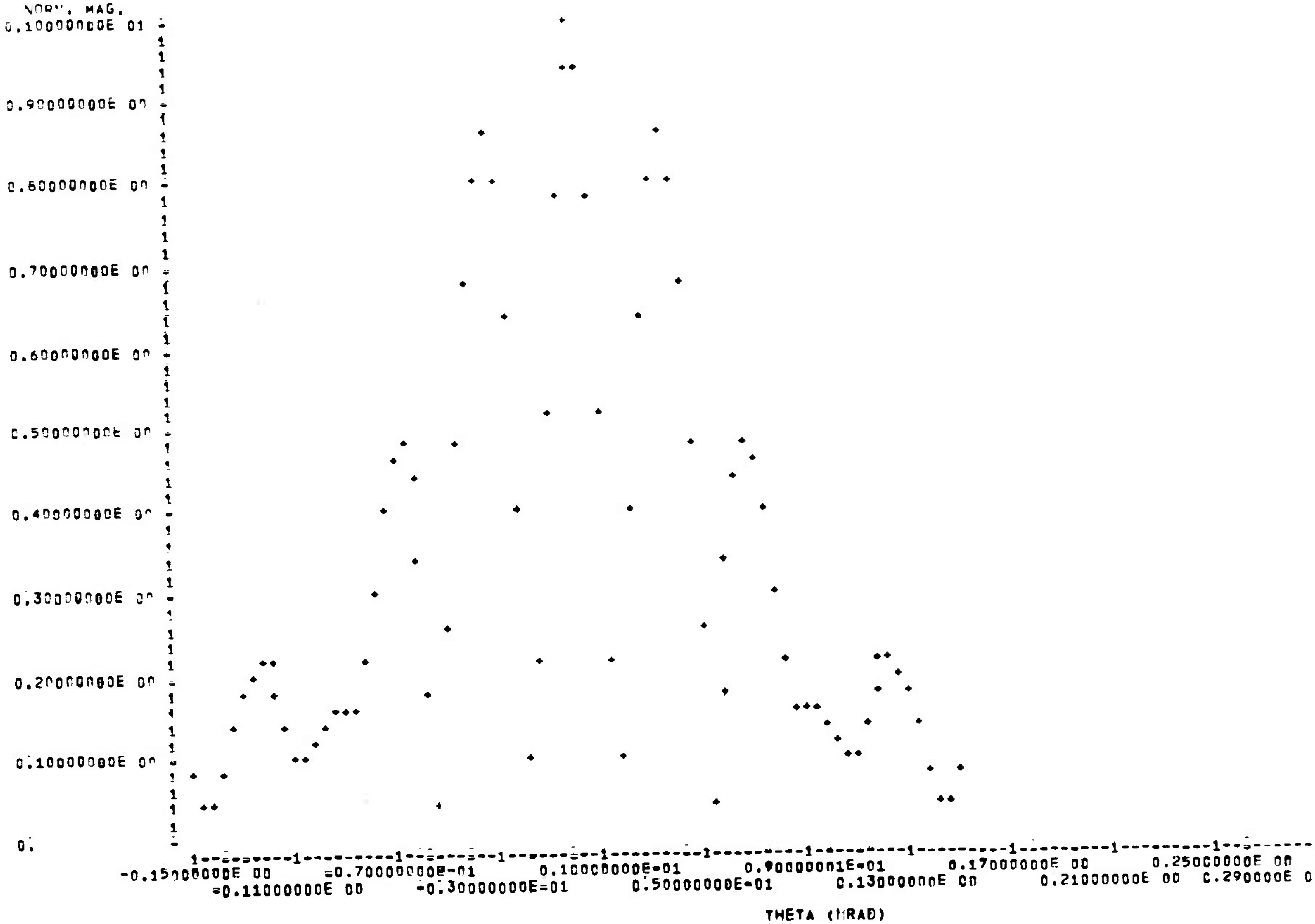
FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.27272727E-02 Y INCREMENT= 0.39317281E 03



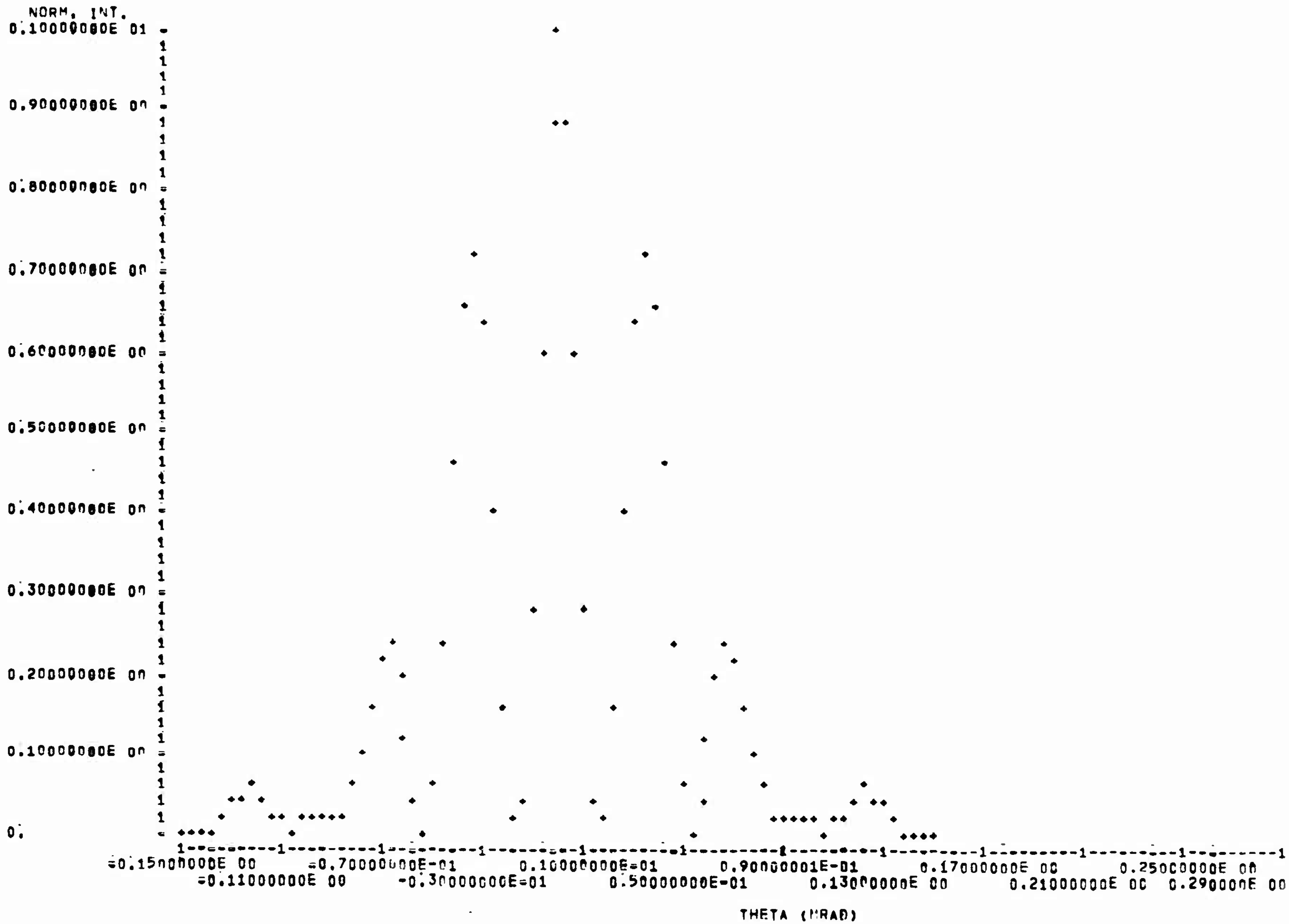
FAR FIELD RESULTS
NUMBER OF POINTS= 81

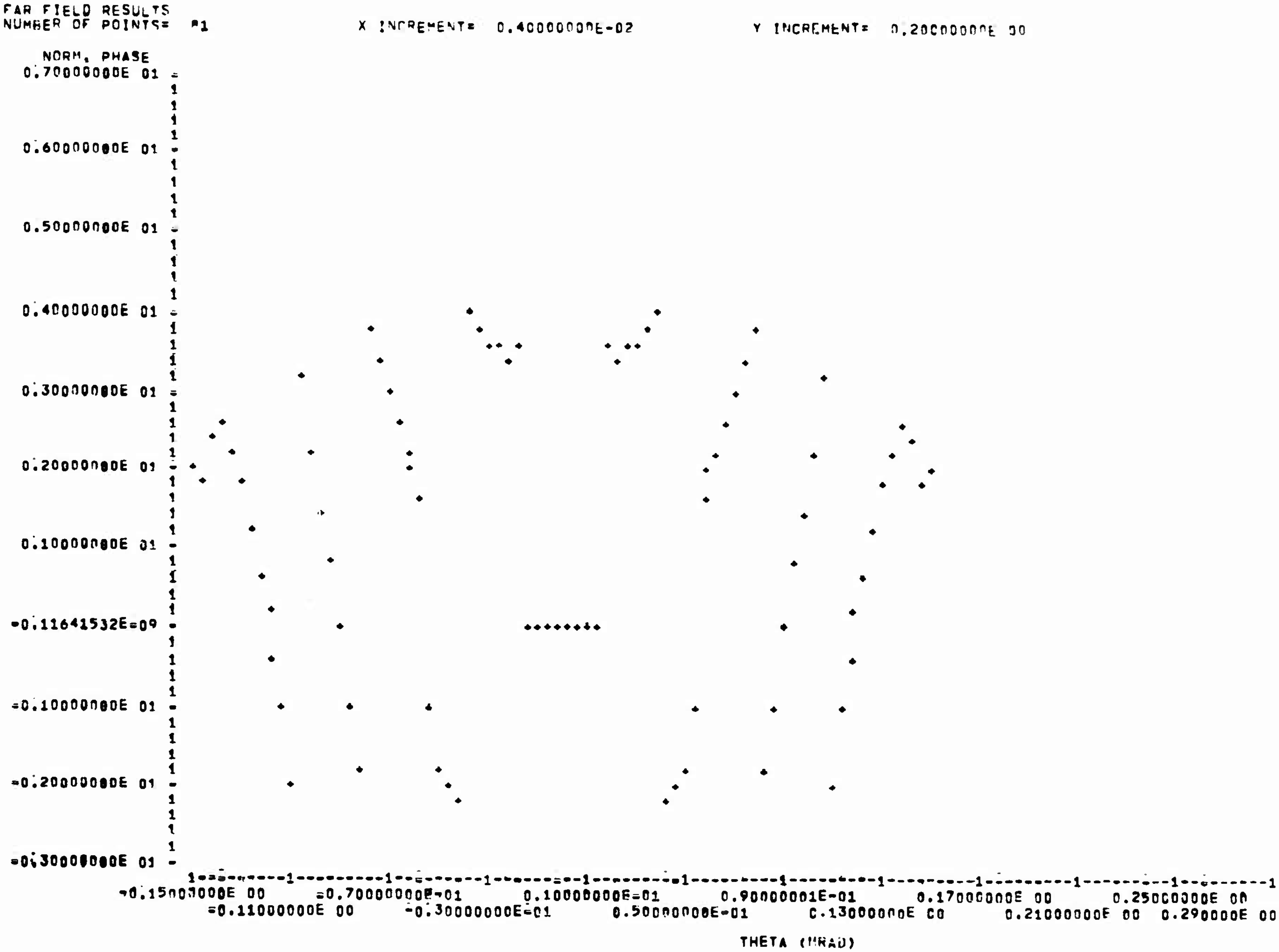
X INCREMENT= 0.40000000E-02

Y INCREMENT= 0.20000000E-01

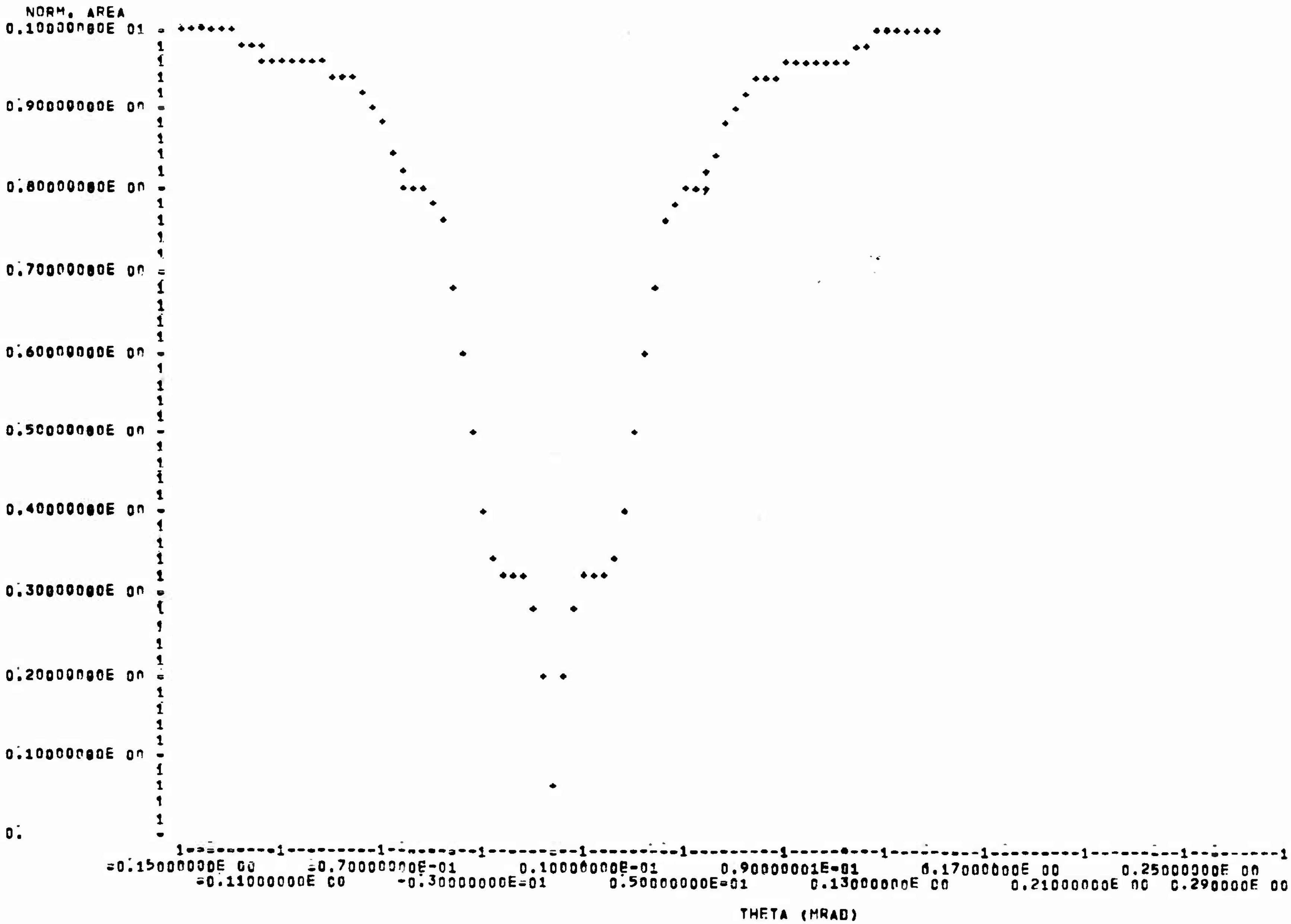


FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.40000000E-02 Y INCREMENT= 0.20000000E-01




FAR FIELD RESULTS
NUMBER OF POINTS= 81
X INCREMENT= 0.40000000E-02
Y INCREMENT= 0.20000000E 00
NORM. PHASE
0.70000000E 01
0.60000000E 01
0.50000000E 01
0.40000000E 01
0.30000000E 01
0.20000000E 01
0.10000000E 01
-0.11641532E-09
-0.10000000E 01
-0.20000000E 01
-0.30000000E 01
-0.15000000E 00
-0.11000000E 00
-0.70000000E-01
-0.30000000E-01
0.10000000E-01
0.50000000E-01
0.90000001E-01
0.13000000E 00
0.17000000E 00
0.21000000E 00
0.25000000E 00
0.29000000E 00
THETA (MRAD)

FAR FIELD RESULTS
NUMBER OF POINTS= 81 X INCREMENT= 0.40000000E-02 Y INCREMENT= 0.20000000E-01



```
FAR FIELD POWER
        WAVE NUMBER  1          0.63366684E 02
```

STARTING PASS 2

APPENDIX C

SSCP DESCRIPTION AND USAGE

I. PROGRAM DESCRIPTION

A. Summary of the SSCP

The Step-by-Step Computer Program (SSCP) shares a number of attributes with the SSCP(ECS) program described earlier in this manual. As an illustration, three of four satellite routines, two of four utility routines, and all four input/output routines of the SSCP(ECS) program are used by both programs. The three routines which are not shared are peculiar to the SSCP(ECS) package and bear no equivalents in the SSCP solution. All three of the primary routines are different, as one might suspect from the definition of a primary routine, though their logic structure is strikingly similar.

The three primary routines used by the SSCP are

PR23	Main program, defines input, contains overall logic
PRPSBS	Propagates one or more waves through free space
PRPGAI	Propagates one or more waves one way through a medium

The three satellite routines shared with SSCP (ECS) are

GAINA	Returns a set of gain values at a particular location in the medium
MIRROR	Reflects one or more waveforms from a particular mirror
SETMIR	Sets up a mirror vector

The two utility routines shared with SSCP(ECS) are

NORM2D	Two-dimensional area conservation (renormalization) routine
RAT3DA	Three-dimensional area conservation routine

The input/output routines are exactly the same as in the SSCP(ECS), namely

AREA21	Computes and prints the area under a curve
PWROUT	Computes and prints the near field power and power transmitted for one or more waves positioned before the output mirror
RSTART	Restarts a previous run by reading a magnetic tape
ALLOUT	The general purpose master subroutine for the GPOP routines

B. Description of Primary Routines

1. PR23 (Main Program)

All important arrays are declared in PR23 and supplied to subprograms through the argument list or by labeled COMMON. This feature permits the user to alter the size of certain arrays as desired to minimize the storage requirement. All arrays dimensioned in PR23 are related to one or more of four quantities: (1) the maximum number of propagating points in the x-direction, (2) the maximum number of last-pass intensity values stored in the z-direction, (3) the largest number of propagation waves, and (4) the largest number of passes that PR23 can handle. These four values are assigned to variables NXDIM, NZDIM, NWDIM, and NPDIM, respectively, and appear in a DATA statement at sequence number 1860. Table 2 describes the relationship between each subscript of each array and the appropriate quantity involved. The abbreviations used in the table are

TABLE 2. PR23 ARRAY SUBSCRIPT REFERENCES

Array Name	Array Type	Subscript Reference No.		
		1	2	3
T	Complex	X	W	-
U	Complex	X	W	-
V	Complex	X	W	-
XMIR1	Complex	X	-	-
XMIR2	Complex	X	-	-
GAIN	Complex	X	W	-
SO	Real	X	Z	W
SONEW	Real	X	W	-
SOTOT	Real	X	W	-
XLAMDA	Real	W	-	-
XKZERO	Real	W	-	-
AMPINT	Real	W	-	-
INFOUT	Real	P	-	-
WOMEGA	Real	W	-	-
X	Real	X	-	-
SOASR	Real	X	-	-
OUT1	Real	X	-	-
OUT2	Real	X	-	-
OUT3	Real	X	-	-
OUT4	Real	X	-	-
OUT5	Real	X	-	-
OUT6	Real	X	-	-
OUT7	Real	X	-	-

T1100

X $\equiv$ NXDIM

Z $\equiv$ NZDIM

W $\equiv$ NWDIM

P $\equiv$ NPDIM

Should the user need to change one or more of the dimensions of PR23, he should first identify which arrays are affected (by Table II) and then change each array declaration in PR23 to reflect the changed dimension. Last, he should change the appropriate value in the DATA statement at sequence number 1860 so that all subprograms will automatically handle the change.

2. Primary Subprogram Descriptions

Only two subprograms are not shared with the SSCP(ECS), these being the primary subroutines responsible for propagation through free space and propagation through a medium. Their logic structure, however, is almost indistinguishable from their ECS counterparts, differing mainly in the different equations used in propagation. For this reason, no further description of these routines will follow other than a listing for each.

C. Input Description

The SSCP and SSCP(ECS) share exactly the same input method, with all but two variables, NX and XWIDTH, retaining their values independent of the program selected. The considerations to be made when determining values for these two variables are presented in Section I-G of the SSCP(ECS) User's Manual.

II. MACHINE UTILIZATION

The SSCP package is written in FORTRAN IV. The program was originally written for a GE635 computer operating under the GECOS III operating system, though this manual reflects changes made allowing the program to run on a CDC 6000 computer operating with the SCOPE monitor (Version 3.4). This requires about 41k (decimal) or 127K (octal) words of memory, of which

$$NXDIM[(NZDIM+8)NWDIM+13]+NPDIM+5NWDIM$$

resides in dimensioned arrays in the main program. For the current dimensioning parameters

$$NXDIM = 301$$

$$NZDIM = 21$$

$$NWDIM = 2$$

$$NPDIM = 101$$

the total storage required for dimensioned variable storage is 21,480 words (decimal) or 52,000 words (octal).

Processor time depends on too many parameters and option settings to be accurately estimated.

III. LISTINGS

```
      PROGRAM PR23(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
     +   TAPE12)
*PR23       PR23--2D STEP-BY-STEP RESONATOR MODEL WITH RESTART              1120
C   NXDIM CHANGES REQUIRE 19 STRING REPLACEMENTS OF #301#                   1140
C   NWAVES CHANGES REQUIRE 7 #,2)#S AND 1 #,2,#                             1160
C                                                                           1180
      EXTERNAL GAINA                                                        1200
C                                                                           1220
      COMPLEX T(301,2),U(301,2),V(301,2),XMIR1(301),XMIR2(301)              1240
      COMPLEX GAIN(301,2)                                                   1260
C                                                                           1280
      DIMENSION SO(301,21,2),SONEW(301,2),SOTOT(301,2)                      1300
      DIMENSION XLAMDA(2),XKZERO(2),AMPINT(2),WOMEGA(2)                     1320
      DIMENSION INFOUT(101)                                                 1340
C                                                                           1360
      COMMON/RCUM/RCUM3D(2)                                                 1380
      COMMON /XARRAY/X(301)                                                 1400
      COMMON /ASPSO/ SOASR(301)                                             1420
      COMMON /OT1/OUT1(301)/OT2/OUT2(301)/OT3/OUT3(301)                     1440
      COMMON /OT4/OUT4(301)/OT5/OUT5(301)/OT6/OUT6(301)                     1460
      COMMON /OT7/OUT7(301)                                                 1480
      COMMON /CGAINA/ GZERO,XIZERO,TEMP(2)                                  1500
C                                                                           1520
      NAMELIST /CASENO/NCASES                                               1540
      NAMELIST/INPUT/CASE,NPASS,IFILE,IRCODE,IROUT,IRTAG,NX,XWIDTH,         1560
     +   NZ,ZLEN,XCENTR,ASR,ZMDLOC,ZLENMD,IGSKIP,GZERO,XIZERO,              1580
     +   NWAVES,XLAMDA,AMPINT,WOMEGA,DIA1,DIA2,REFL1,REFL2,                 1600
     +   RCURV1,RCURV2,OMEGA1,OMEGA2,TILT1,TILT2,TLOSS1,INFOUT              1620
      NAMELIST/RUNOPT/NPASS,IFILE,IRCODE,IROUT,IRTAG                        1640
      NAMELIST/CAVITY/NX,XWIDTH,NZ,ZLEN,XCENTR,DX,DZ                        1660
      NAMELIST/MEDIUM/ZMDLOC,ZLENMD,IGSKIP,                                 1680
     +   NZMED,NZDIV,NZSTPD,ZLEN1,ZLEN2                                     1700
      NAMELIST /GAINC/GZERO,XIZERO                                          1720
      NAMELIST/WAVES/NWAVES,XLAMDA,AMPINT,WOMEGA,XKZERO,STAB                1740
      NAMELIST/MIRRRS/DIA1,DIA2,REFL1,REFL2,RCURV1,RCURV2,                  1760
     +  OMEGA1,OMEGA2,TILT1,TILT2,TLOSS1,ASR,NXC1,NXC2                      1780
      NAMELIST /NRFLD/INFOUT                                                1800
C                                                                           1820
      DATA PI/3.14159265/,PROG/4HPR23/                                      1840
      DATA NXDIM,NZDIM,NWDIM,NPDIM/301,21,2,101/                            1860
C                                                                           1880
      DATA TIME,DATE/1H ,1H /
      DATA SNMB/1H /
C                                                                           1940
C           READ NUMBER OF CASES TO BE ANALYZED AND                         1960
C           INITIALIZE MATRICES BEFORE EACH CASE                            1980
C                                                                           2000
      READ(5,CASENO)                                                        2020
      DO 999 ICASE=1,NCASES                                                 2040
      DO 30 K=1,NWDIM                                                       2060
      DO 30 I=1,NXDIM                                                       2080
      DO 30 J=1,NZDIM                                                       2100
   30 SO(I,J,K)=0.                                                          2120
      DO 40 I=1,NPDIM                                                       2140
   40 INFOUT(I)=0                                                           2160
C                                                                           2180
C             DEFINE INPUT PARAMETERS                                       2200
```

```
      C
      C---------------READ TITLE AND RUN OPTIONS---------------
            READ(5,INPUT)
            WRITE(IFILE,9005) PROG,CASE
            WRITE(IFILE,RUNOPT)
      C------------DEFINE CAVITY----------------
            DX=XWIDTH/FLOAT(NX-1)
            DZ=ZLEN/FLOAT(NZ-1)
            ICENT = (NX+1)/2
            DO 50 I=1,NX
       50   X(I)=XCENTR+FLOAT(I-ICENT)*DX
            WRITE(IFILE,CAVITY)
      C---------DEFINE MEDIUM------------
            NZMED=ZLENMD/DZ+.999
            NZSTPD=FLOAT(NZMED+1)/FLOAT(NZDIM)+.999
            IF(NZMED.NE.0) NZDIV=FLOAT(NZMED)/FLOAT(NZSTPD)+.999
            ZLEN1=AINT((ZMDLOC-ZLENMD/2.)/DZ)*DZ
            ZLEN2=ZLEN-ZLENMD-ZLEN1
            WRITE(IFILE,MEDIUM)
      C------------DEFINE GAIN CONSTANTS---------------------
            WRITE(IFILE,GAINC)
      C----------DEFINE WAVE(S)---------------
            XKMAX=-1.E30
            ICENT=(NX+1)/2
            XZERO=X(ICENT)
            DO 110 IWAVE=1,NWAVES
            XKZERO(IWAVE)=2.*PI/XLAMDA(IWAVE)
            XKMAX=AMAX1(XKMAX,XKZERO(IWAVE))
            DO 100 I=1,NX
            IF(WOMEGA(IWAVE).EQ.0.) U(I,IWAVE)=AMPINT(IWAVE)
            IF(WOMEGA(IWAVE).NE.0.) U(I,IWAVE)=
           +   AMPINT(IWAVE)*EXP(-((X(I)-XZERO)/WOMEGA(IWAVE))**2)
      100   CONTINUE
            U(1,IWAVE)=0.
            U(NX,IWAVE)=0.
      110   CONTINUE
            STAB=.5*XKMAX*DX*DX
            IF(DZ.GT.STAB) WRITE(IFILE,9007) DZ,STAB
            IF(IRCODE.GT.0) CALL RSTART(IFILE,IRCODE,IRTAG,NWAVES,NXDIM,
           +   NZDIM,U,SO)
            WRITE(IFILE,WAVES)
            IF(IRCODE.GT.0) REWIND IRCODE
      C---------DEFINE MIRRORS-----------
            NXC1=(DIA1-1.17737*OMEGA1)/DX+.5
            IF(MOD(NXC1,2).NE.0) NXC1=NXC1-1
            NXC2=(DIA2-1.17737*OMEGA2)/DX+.5
            IF(MOD(NXC2,2).NE.0) NXC2=NXC2-1
            CALL SETMIR(NX,NXC1,DX,XKZERO,REFL1,RCURV1,OMEGA1,TILT1,XMIR1)
            CALL SETMIR(NX,NXC2,DX,XKZERO,REFL2,RCURV2,OMEGA2,TILT2,XMIR2)
            WRITE(IFILE,MIRRRS)
      C----------DEFINE NEAR FIELD PRINT OPTIONS------------
            WRITE(IFILE,9008) (I,I=1,NPASS)
            WRITE(IFILE,9009) (INFOUT(I),I=1,NPASS)
      C
      C       SETUP 3D CONVERSION MATRIX
      C
            XMAX=DX*FLOAT(NXC2)+2.*OMEGA2
```

```
      DO 120 I=1,NX
  120 SOASR(I)=ASR*ABS(X(I)-X(ICENT))/XMAX
C
C              WRITE INPUT MATRICES
C
C-----------MIRRORS-------------
      CALL ALLOUT(IFILE,NX,1,5,19,19HMIRROR DESCRIPTIONS,
     + 1,10,1,1HX,X,OUT1,
     +  2,114,12,12HMIRROR 1 INT,XMIR1,OUT2,
     +  2,115,14,14HMIRROR 1 PHASE,XMIR1,OUT3,
     +  2,114,12,12HMIRROR 2 INT,XMIR2,OUT4,
     +  2,115,14,14HMIRROR 2 PHASE,XMIR2,OUT5)
C-----------------INPUT WAVE(S)------------------
      DO 140 IWAVE=1,NWAVES
      CALL ALLOUT(IFILE,NX,1,5,22,22HINPUT WAVE DESCRIPTION,
     +  1,10,1,1HX,X,OUT1,
     +  2,113,9,9HMAGNITUDE,U(1,IWAVE),OUT2,
     +  2,114,9,9HINTENSITY,U(1,IWAVE),OUT4,
     +  2,116,10,10HPHASE (DG),U(1,IWAVE),OUT5,
     +  2,1000114,9,9HNORM AREA,U(1,IWAVE),OUT3)
      CALL PWROUT(IFILE,NX,NXC1,ASR,DX,OMEGA1,TLOSS1,REFL1,
     +  U(1,IWAVE),PWRNF,PWROT)
  140 CONTINUE
C
C            GENERATE RESTART TAPE LABEL
C
      IF(IROUT.LE.0) GO TO 200
      WRITE(IROUT)TIME,DATE,SNMB,PROG,CASE
      NZGAIN=1
      IF(NZMED.GT.0) NZGAIN=FLOAT(NZMED)/FLOAT(NZSTPD)+1.9999
      WRITE(IROUT)NX,NZGAIN,NWAVES,(I,I=1,7),(X(1),I=1,10)
      IPASS=0
      WRITE(IROUT)IPASS
      WRITE(IROUT)  ((U(I,J),I=1,NX),J=1,NWAVES)
      WRITE(IROUT)  (((SO(I,J,K),I=1,NX),J=1,NZGAIN),K=1,NWAVES)
  200 CONTINUE
C
C            BEGIN MAIN PROPAGATION LOOP
C
      DO 900 IPASS=1,NPASS
      WRITE(IFILE,9010) IPASS,CASE
C----------NORMALIZE PROPAGATION MATRIX, IF NECESSARY-----------
      IF((ZLENMD.EQ.0.) .AND. (ASR.EQ.0.))
     + CALL NORM2D(IFILE,NX,NXDIM,NWAVES,DX,U)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 24,24HAREA(S) AT START OF PASS,DX,U,ASR,AREA2D,AREA3D)
      DO 400 I=1,NWAVES
  400 RCUM3D(I)=1.
C----------MAKE ROUND TRIP PASS-------------
      CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR1)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 19,19HAFTER OUTPUT MIRROR,DX,U,ASR,AREA2D,AREA3D)
      CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN1,0.,XKZERO,ASR,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
      CALL PRPGAI(ZLEN1,NZSTPD,NZDIV,NXDIM,NZDIM,NX,IGSKIP,NWAVES,+1,
     + DX,DZ,ZLENMD,XKZERO,ASR,T,U,V,SO,SONEW,SOTOT,GAIN,GAINA)
```

```
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +   12,12HAFTER MEDIUM,DX,U,ASR,AREA2D,AREA3D)
      CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN2,ZLEN1+ZLENMD,
     +   XKZERO,ASR,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
      IF(ASR.GT.0.) WRITE(IFILE,9090) (RCUM3D(I),I=1,NWAVES)
      DO 500 I=1,NWAVES
  500 RCUM3D(I)=1.
      CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR2)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +   17,17HAFTER BACK MIRROR,DX,U,ASR,AREA2D,AREA3D)
      CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN2,0.,XKZERO,ASR,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
      CALL PRPGAI(ZLEN2,NZSTPD,NZDIV,NXDIM,NZDIM,NX,IGSKIP,NWAVES,-1,
     +  DX,DZ,ZLENMD,XKZERO,ASR,T,U,V,SO,SONEW,SOTOT,GAIN,GAINA)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +   12,12HAFTER MEDIUM,DX,U,ASR,AREA2D,AREA3D)
      CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN1,ZLEN2+ZLENMD,
     +   XKZERO,ASR,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
      IF(ASR.GT.0.) WRITE(IFILE,9090) (RCUM3D(I),I=1,NWAVES)
C-------------OUTPUT FOR ROUND TRIP PASS-------------
      WRITE(IFILE,9060) IPASS
      DO 600 IWAVE=1,NWAVES
      CALL PWROUT(IFILE,NX,NXC1,ASR,DX,OMEGA1,TLOSS1,REFL1,
     +   U(1,IWAVE),PWRNF,PWROT)
      IF(INFOUT(IPASS).GE.1)
     +   CALL ALLOUT(IFILE,NX,1,7,27,27HN.F. RESULTS FOR ROUND TRIP,
     +  1,10,1,1HX,X,OUT1,
     +  2,113,9,9HMAGNITUDE,U(1,IWAVE),OUT2,
     +  2,114,9,9HINTENSITY,U(1,IWAVE),OUT3,
     +  2,220113,10,10HNORM. MAG.,U(1,IWAVE),OUT4,
     +   2,220114,10,10HNORM. INT.,U(1,IWAVE),OUT5,
     +  2,110115,11,11HNORM. PHASE,U(1,IWAVE),OUT6,
     +  2,1000114,10,10HNORM. AREA,U(1,IWAVE),OUT7)
  600 CONTINUE
C----------WRITE INFORMATION ON RESTART TAPE-----------
      IF(IROUT.GT.0) WRITE(IROUT) IPASS
      IF(IROUT.GT.0) WRITE(IROUT) ((U(I,J),I=1,NX),J=1,NWAVES)
      IF(IROUT.GT.0) WRITE(IROUT) (((SO(I,J,K),I=1,NX),
     +   J=1,NZGAIN),K=1,NWAVES)
C-------------TERMINATION OF PROPAGATION LOOP-------------
  900 CONTINUE
C
C         PROGRAM TERMINATION
C
      IF(IROUT.GT.0) ENDFILE IROUT
  999 CONTINUE
      STOP
C
C                FORMATS
C
 9005 FORMAT(1H1,7HPROGRAM, 5X, A6/1X,4HCASE,8X,F6.2)
 9007 FORMAT(1H1,25(/130(1H*))/30X,7HDELTA Z, E20.7,
```

```
          +    2X,31HGREATER THAN STABILITY CRITERIA,E20.7,25(/130(1H*)))         5700
     9008 FORMAT(1H0,11HPASS NUMBER/(1X,43I3))                                    5720
     9009 FORMAT(1X,17HNF OUTPUT OPTIONS/(1X,40I3))                               5740
     9010 FORMAT(1H1,20HSTARTING PASS NUMBER,I5,10H FOR CASE ,F6.2)
     9060 FORMAT(1H0,20HFINISHED PASS NUMBER,I5)
     9090 FORMAT(1H0,5X,17HCUMULATIVE RATIOS/(5X,E15.7))
          END                                                                     5820
```

```
      SUBROUTINE PRPGAI(ZSTART,NZSTPD,NZD,NXDIM,NZDIM,NX,IGSKIP,IWAVE,       5900
     +   IDIR,DX,DZZ,ZLEN,XK0,ASR,T,U,V,SO,SONEW,SOTOT,GAIN,GAINS)           5920
      COMPLEX T(NXDIM,IWAVE),U(NXDIM,IWAVE),V(NXDIM,IWAVE),GY(10),A          5940
      DIMENSION SONEW(NXDIM,IWAVE),SOTOT(NXDIM,IWAVE),                       5960
     +   SO(NXDIM,NZDIM,IWAVE)                                               5980
      COMPLEX GAIN(NXDIM,IWAVE),GNX                                          6000
      DIMENSION XK0(IWAVE),CEX(10),R(10)                                     6020
      COMMON /ASRSO/SOASR(1)                                                 6040
C---------ASF TO COMPUTE INTENSITY OF A COMPLEX NUMBER-------                6060
      XINTY(A)=REAL(A)**2+AIMAG(A)**2                                        6080
C                                                                            6100
C-------------------------------------------------------------               6120
C--PRPGAI---PROPAGATES (IWAVE) WAVEFORMS THROUGH A GAIN MEDIUM               6140
C           OF LENGTH (ZLEN) ASSUMING CONSTANT DX AND DZ                     6160
C-----------------------------------------------------------------           6180
C   THE PARAMETERS ARE                                                       6200
C                                                                            6220
C ZSTART CURRENT DISTANCE FROM LAST MIRROR                                   6240
C NZSTPD-NO. OF Z-STEPS/DIVISION                                             6260
C NZD----NUMBER OF Z-DIVISIONS                                               6280
C NXDIM--THE X-DIMENSION OF THE SO MATRIX                                    6300
C NZDIM--THE Z-DIMENSION OF THE SO MATRIX                                    6320
C NX-----THE NUMBER OF X POINTS                                              6340
C IGSKIP-SKIP PARAMETER FOR GAIN CALL                                        6360
C IWAVE--NUMBER OF WAVES TO PROPAGATE                                        6380
C IDIR---DIRECTION INDICATOR FOR SO ACCESS                                   6400
C   .EQ.  1  INCREASING Z                                                    6420
C   .EQ. -1  DECREASING Z                                                    6440
C DX-----DELTA X FOR PROPAGATION MATRIX                                      6460
C DZ-----DELTA Z FOR ONE PROPAGATION STEP (APPROXIMATE,                      6480
C        ADJUSTED SLIGHTLY BY ROUTINE)                                       6500
C ZLEN---TOTAL PROPAGATION LENGTH                                            6520
C XK0----K = 2 PI/LAMBDA (DIM. AT LST IWAVE)                                 6540
C ASR----3D AREA ADJUSTMENT FACTOR (SWITCH FOR CALL TO RAT3DA)               6560
C T------DUMMY MATRIX (COMPLEX, DIM. NXDIM BY IWAVE)                         6580
C U------INPUT/ OUTPUT WAVE MATRIX (COMPLEX)                                 6600
C V------DUMMY MATRIX (COMPLEX)                                              6620
C SO-----INTENSITY MATRIX (REAL, DIM. NXDIM BY NZDIM BY IWAVE)               6640
C SONEW--DUMMY MATRIX (DIM. NXDIM BY IWAVE)                                  6660
C SOTOT--DUMMY MATRIX (DIM. NXDIM BY IWAVE)                                  6680
C GAIN---GAIN MATRIX (REAL, DIMENSIONED NXDIM BY IWAVE)                      6700
C GAINS--GAIN ROUTINE NAME (TYPED EXTERNAL IN MAIN PROGRAM)                  6720
C                                                                            6740
C   SUBPROGRAMS NECESSARY--GAINS,RAT3DA                                      6760
C                                                                            6780
C   CHANGED 1-25-73                                                          6800
C   CHANGED  9/19/73 (ZSTART ADDED--SKIPS BPROP WHEN .GT. 0.)                6820
C                                                                            6840
C-------------------------------------------------------------------         6860
C                                                                            6880
      IGCNT=0                                                                6900
      NXM1=NX-1                                                              6920
      IF(ZLEN.LE.0.) GO TO 999                                               6940
C-----------COMPUTE PROPAGATION CONSTANTS-----------                         6960
      DO 20 JWAVE=1,IWAVE                                                    6980
      EX=DZZ/(XK0(JWAVE)*DX*DX)                                              7000
      CEX(JWAVE)=EX*EX                                                       7020
```

```
      R(JWAVE)=1./(1.+CEX(JWAVE))
   20 GY(JWAVE)=EX*(0.,1.)
C
C          PROPAGATE OVER DISTANCE ZLEN USING NZD*NZSTPD STEPS
C
      DO 500 IZD=1,NZD
      DO 300 J=1,NZSTPD
C---------COMPUTE SUM CF OLD AND NEW INTENSITIES---------
      R1=FLOAT(J-1)/FLOAT(NZSTPD)
      DO 50 JWAVE=1,IWAVE
      DO 50 K=1,NX
      SK=XINTY(U(K,JWAVE))
      IF(IDIR.NE.(-1)) L=IZD
      IF(IDIR.EQ.(-1)) L=NZD+2-IZD
      IF(IDIR.NE.(-1)) L2=L+1
      IF(IDIR.EQ.(-1)) L2=L-1
      IF(J.NE.1) GO TO 40
      SOTOT(K,JWAVE)=SO(K,L,JWAVE)
      SONEW(K,JWAVE)=SK
      GO TO 45
   40 SOTOT(K,JWAVE)=SO(K,L,JWAVE)+R1*(SO(K,L2,JWAVE)-SO(K,L,JWAVE))
   45 SOTOT(K,JWAVE)=SOTOT(K,JWAVE)+SK
   50 IF(ASR.NE.0.) SOTCT(K,JWAVE)=SOTOT(K,JWAVE)*SOASR(K)
C-----------COMPUTE GAIN FOR FOLLOWING PROPAGATION STEP-----------
      IF(MOD(IGCNT,IGSKIP).EQ.0) CALL GAINS(NX,NXDIM,IWAVE,SOTOT,GAIN)
      IGCNT=IGCNT+1
C-----------PROPAGATE ONE STEP-------------
      IF(ZSTART.GT.0. .OR. (IZD+J).GT.2) GO TO 200
C-----------(BPROP STEP)------------
      DO 120 JWAVE=1,IWAVE
      DO 120 I=2,NXM1
  120 V(I,JWAVE)=U(I,JWAVE)+(GY(JWAVE)/2.)*(U(I+1,JWAVE)-
     +   2.*U(I,JWAVE)+U(I-1,JWAVE))
      GO TO 280
C-----------(PROP STEP)------------
  200 DO 250 JWAVE=1,IWAVE
      DO 250 I=2,NXM1
  250 V(I,JWAVE)=
     +  R(JWAVE)*(T(I,JWAVE)+GY(JWAVE)*(U(I+1,JWAVE)-2.*T(I,JWAVE)+
     +  U(I-1,JWAVE))+
     +  CEX(JWAVE)*(U(I+1,JWAVE)-T(I,JWAVE)+U(I-1,JWAVE)))
      IF(ASR.NE.0.) CALL RAT3DA(NX,NXDIM,IWAVE,DX,DX,V,U)
C----------MOVE ARRAYS DOWN AND APPLY GAIN------------
  280 DO 290 JWAVE=1,IWAVE
      DO 290 I=2,NXM1
      GNX=CEXP(DZZ*CMPLX(.5*REAL(GAIN(I,JWAVE)),AIMAG(GAIN(I,JWAVE))))
      T(I,JWAVE)=U(I,JWAVE)*GNX
  290 U(I,JWAVE)=V(I,JWAVE)*GNX
C-----------LOAD NEW LINE INTO PAST INTENSITIES MATRIX----------
  300 CONTINUE
      DO 400 JWAVE=1,IWAVE
      DO 400 I=1,NX
  400 SO(I,L,JWAVE)=SONEW(I,JWAVE)
C----------ADJUST V AND SO MATRICES AT  Z=ZLEN-------------
  500 CONTINUE
      DO 600 JWAVE=1,IWAVE
      DO 600 I=1,NX
```

```
                V(I,JWAVE)=U(I,JWAVE)                                        8180
          600   SO(I,L2,JWAVE)=XINTY(V(I,JWAVE))                             8200
          C---------PROPAGATION TC Z=ZLEN COMPLETE-----------------          8220
          999   RETURN                                                       8240
                END                                                          8260
```

```
      SUBROUTINE PRPSBS(IWAVE,NXDIM,NX,DX,DZ,ZLEN,ZSTART,XK0,ASR,T,U,V)
      COMPLEX T(NXDIM,IWAVE),U(NXDIM,IWAVE),V(NXDIM,IWAVE),GY(10)
      DIMENSION XK0(IWAVE),CEX(10),R(10)
C
C-------------------------------------------------------------
C--PRPSBS---PROPAGATES A WAVEFORM OVER A DISTANCE ZLEN ASSUMING
C          CONSTANT DX AND DZ
C
C   THE PARAMETERS ARE
C
C IWAVE--THE NUMBER OF PROPAGATING WAVES
C NXDIM--THE X-DIMENSION OF THE PROPAGATION MATRIX
C NX-----THE NUMBER OF X POINTS
C DX-----DELTA X FOR PROPAGATION MATRIX
C DZ-----DELTA Z FOR PROPAGATION STEP(APPROXIMATE--ADJUSTED
C          SLIGHTLY BY ROUTINE)
C ZLEN---TOTAL PROPAGATION LENGTH
C ZSTART CURRENT DISTANCE FROM LAST MIRROR
C XK0----K = 2 PI/LAMBDA (VECTOR, DIM AT LST IWAVE)
C ASR----3D AREA ADJUSTMENT FACTOR(USED FOR SWITCH FOR RAT3DA)
C T------DUMMY MATRIX(COMPLEX, DIMENSIONED NXDIM BY IWAVE)
C U------INPUT WAVE/OUTPUT WAVE MATRIX (COMPLEX)--IS MODIFIED
C V------DUMMY VECTOR (COMPLEX)
C
C   SUBPROGRAMS NECESSARY--RAT3DA (IF ASR .NE. 0.)
C
C   CHANGED 9/19/73 (ZSTART ADDED--SKIPS BPROP WHEN .GT. 0.)
C
C-------------------------------------------------------------
C
      IF(ZLEN.LE.0.) GO TO 999
      NXM1=NX-1
      NSTEP=ZLEN/DZ+.9999
      DZZ=ZLEN/FLOAT(NSTEP)
C---------COMPUTE PROPAGATION CONSTANTS---------
      DO 50 JWAVE=1,IWAVE
      EX=DZZ/(XK0(JWAVE)*DX*DX)
      CEX(JWAVE)=EX*EX
      R(JWAVE)=1./(1.+CEX(JWAVE))
   50 GY(JWAVE)=EX*(0.,1.)
C-----------TAKE ONE BPROP STEP--------
      IF(ZSTART.GT.0.) GO TO 200
      DO 150 JWAVE=1,IWAVE
      DO 100 I=2,NXM1
  100 V(I,JWAVE)=U(I,JWAVE)+(GY(JWAVE)/2.)*
     +  (U(I+1,JWAVE)-2.*U(I,JWAVE)+U(I-1,JWAVE))
      V(1,JWAVE)=0.
  150 V(NX,JWAVE)=0.
      DO 170 JWAVE=1,IWAVE
      DO 170 I=1,NX
      T(I,JWAVE)=U(I,JWAVE)
  170 U(I,JWAVE)=V(I,JWAVE)
      IF(NSTEP.EQ.1) GO TO 999
C-----------TAKE (NSTEP-1) PROPAGATION STEPS-----------
  200 CONTINUE
      DO 500 JWAVE=1,IWAVE
      DO 400 J=2,NSTEP
```

```
      DO 300 I=2,NXM1
      V(I,JWAVE)=
     +  R(JWAVE)*(T(I,JWAVE)+GY(JWAVE)*(U(I+1,JWAVE)-2.*T(I,JWAVE)+
     +  U(I-1,JWAVE))+CEX(JWAVE)*(U(I+1,JWAVE)-T(I,JWAVE)+U(I-1,JWAVE)))
  300 CONTINUE
      IF(ASR.NE.0.) CALL RAT3DA(NX,NXDIM,IWAVE,DX,DX,V,U)
      DO 350 I=1,NX
      T(I,JWAVE)=U(I,JWAVE)
  350 U(I,JWAVE)=V(I,JWAVE)
  400 CONTINUE
  500 CONTINUE
  999 RETURN
      END
```

APPENDIX D

SAMPLE CASE FOR SSCP(ECS)

The case (named "8.45") described by the input data below involves 10 round-trip passes with restart information to be written on file code 10 (a control card must appear elsewhere in the deck assigning file code 10 to a new, or scratch, magnetic tape) and normal program output to be directed to file code 6. The input, or starting, waveform for this case is not to be taken from a restart tape but is, instead, to be generated by parameters described below. The number of mesh points along the x-axis (across the face of a mirror) is to be 81, and the minimum width over which these 81 points are to be defined is 9 cm (see Fig. 4). There are to be 101 mesh points (100 steps) between mirrors, where the mirrors are 10,000 cm apart. The x-value of the mirror centerline is to be 0. The analysis will be two-dimensional (ASR = 0.). The medium, whose center is located 5000 cm from the output mirror, is to be 5000 cm in width, thereby filling half the cavity. The gain routine, to be called at every propagation step in the Z-direction, is supplied two parameters – g_o and I_o, with values 3.5×10^{-4} and 100., respectively. One wave of wavelength 3×10^{-4} cm and uniform initial amplitude 1.0 is to be propagated. The initial wave does not have a gaussian structure. The output mirror has a diameter of 5.74 cm, 100% reflectivity, a radius of curvature of -2×10^4 cm, an edge taper of 0.45 cm, no tilt, and no loss in the mirror itself (meaningless in this case since the reflectivity was total). The back mirror has a diameter of 11.1 cm, 100% reflectivity, a radius of curvature of 4×10^4 cm, an edge taper of 0.6 cm, and no tilt. Normal output is desired for all 10 passes.

Sample Input Deck

(column 2)

```
$CASENO NCASES=1$

$INPUT
   CASE=8.45, NPASS=10, IFILE=6, IRCODE=0, IROUT=10,
   IRTAG=0, NX=81, XWIDTH=9., NZ=101, ZLEN=10000.,
   XCENTR=0., ASR=0., ZMDLOC=5000., ZLENMD=5000.,
   IGSKIP=1, GZERO=3.5E-4, XIZERO=100., NWAVES=1,
   XLAMDA(1)=3.E-4, AMPINT(1)=1., WOMEGA(1)=0.,
   DIA1=5.74, REFL1=1.0, RCURV1=-2.E4, OMEGA1=.45,
   TILT1=0., TLOSS1=0., DIA2=11.1, REFL2=1.0, RCURV2=4.E4,
   OMEGA2=.6, TILT2=0., INFOUT(1)=10*1$
```

The output produced by either the SSCP or SSCP(ECS) for the data above consists of three major groups. The two that are not optional are the summation of the data input defining the case and the summary information printed during each round-trip propagation. The first includes the following information:

1. Repetition of the information read
2. Descriptions of both mirror matrices (intensity and phase listings and plots for each)
3. Description of each input wave (magnitude, intensity, phase, and normalized area listings and plots for each).

The round-trip summary information is self-explanatory, basically monitoring the area of the propagating wave as it proceeds through a round-trip pass.

The third type of output (optional) that can be produced summarizes the waveform itself at the conclusion of a round-trip pass. The magnitude, intensity, normalized magnitude, normalized intensity, normalized phase, and normalized area are listed and plotted versus their corresponding x-location.

The following pages represent the output produced by the sample data case. All three types of output are represented.

```
 PROGRAM      PR51
 CASE           8.45

NAMELIST    RUNOPT
NPASS            10    IFILE               6    IRCODE              0    IRCUT               10    IRTAG               0
END    NAMELIST    RUNOPT

NAMELIST    CAVITY
NX               81
XWIDTH    0.90000000E 01
NZ              101
ZLEN      0.10000000E 05        RCURV1   -0.20000000E 05     RCURV2    0.40000000E 05     XCENTR    0.
ASP       0.                    DXMIR1    0.11250000E 00     DXMIR2    0.22500000E 00     DXOUT     0.22500000E 00
VR1       0.10000000E 05        VR2       0.10000000E 31     G1        0.66666666E 00     G2        0.13333333E 01
ISHIFT            4    NG                 85
END    NAMELIST    CAVITY

NAMELIST    MEDIUM
ZMDLOC    0.50000000E 04        ZLENMD    0.50000000E 04
IGSKIP            1    NZMED              50    NZDIV              17    NZSTPD               3
ZLEN1     0.25000000E 04        ZLEN2     0.25000000E 04
END    NAMELIST    MEDIUM

NAMELIST    GAINC
GZERO     0.35000000E-03        XIZERO    0.10000000E 03
END    NAMELIST    GAINC

NAMELIST    WAVES
NWAVES              1
XLAMDA(I)
     1    0.30000000E-03    0.
AMPINT(I)
     1    0.10000000E 01    0.
WOMEGA(I)
     1    0.                0.
XKZERO(I)
     1    0.20943951E 05    0.
STAB      0.13253594E 03
END    NAMELIST    WAVES

NAMELIST    MIRRRS
DIA1      0.57400000E 01        DIA2      0.11100000E 02     REFL1     0.10000000E 01     REFL2     0.10000000E 01
OMEGA1    0.45000000E 00        OMEGA2    0.60000000E 00     TILT1     0.                 TILT2     0.
TLOSS1    0.
NXC1             46    NXC2               45    NXCOUT             23
END    NAMELIST    MIRRRS

 PASS NUMBER
   1  2  3  4  5  6  7  8  9 10
 NF OUTPUT OPTIONS
   1  1  1  1  1  1  1  1  1  1
```

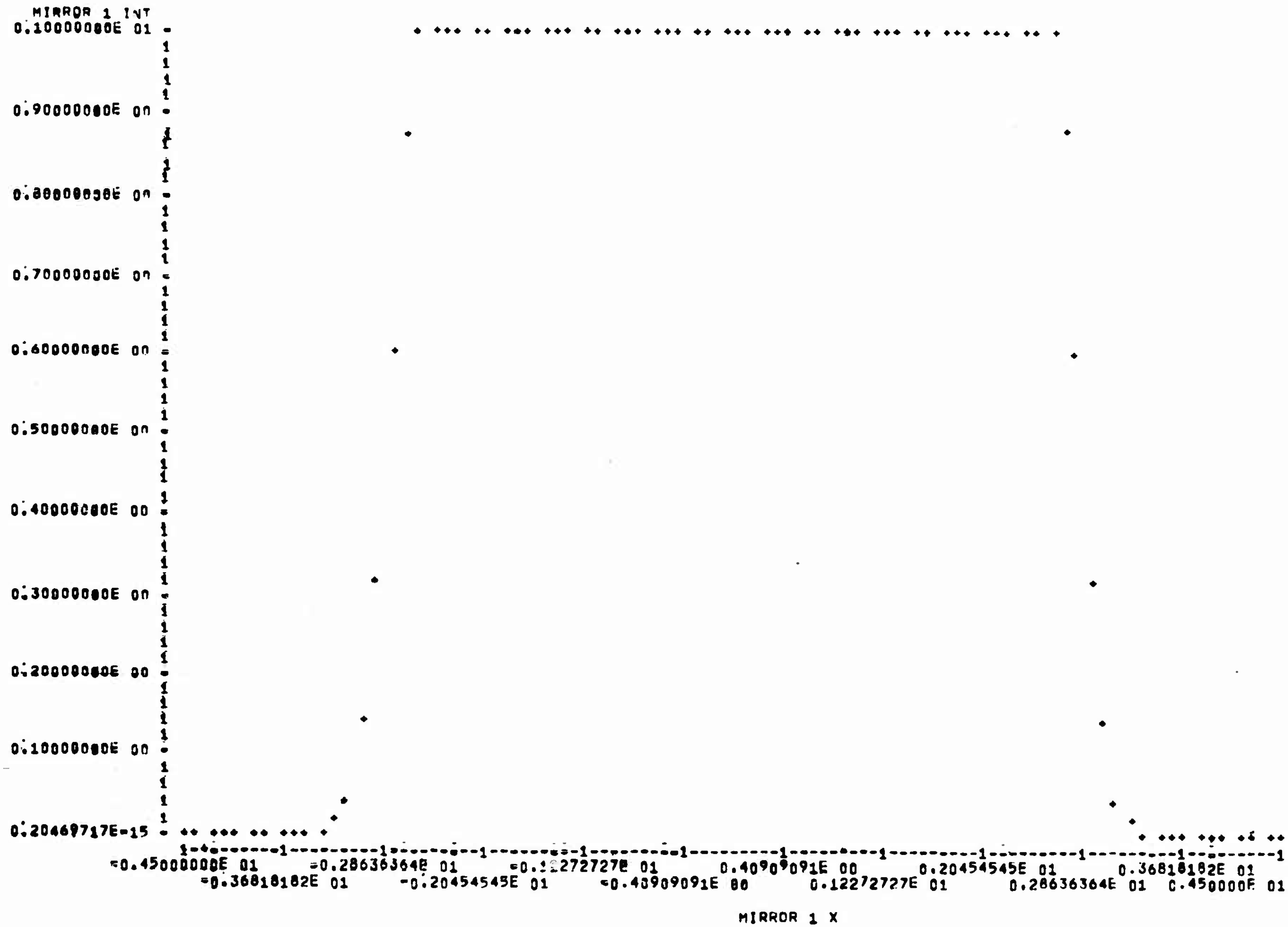
MIRROR DESCRIPTIONS

I	MIRROR 1 X	MIRROR 1 INT	MIRROR 1 PHASE	MIRROR 2 X	MIRROR 2 INT	MIRROR 2 PHASE
1	-0.45000000E 01	0.20469717E-15	0.	-0.90000000E 01	0.50118913E-35	0.
2	-0.43875000E 01	0.12664166E-13	0.	-0.87750000E 01	0.53801861E-31	0.
3	-0.42750000E 01	0.61019367E-12	0.	-0.85500000E 01	0.32908078E-27	0.
4	-0.41625000E 01	0.22897348E-10	0.	-0.83249999E 01	0.11468766E-23	0.
5	-0.40500000E 01	0.66[illegible]15861E-09	0.	-0.81000000E 01	0.22774057E-20	0.
6	-0.39375000E 01	0.15229980E-07	0.	-0.78750000E 01	0.25767571E-17	0.
7	-0.38250000E 01	0.26995786E-06	0.	-0.76500000E 01	0.16611770E-14	0.
8	-0.37125000E 01	0.37266532E-05	0.	-0.74250000E 01	0.61019381E-12	0.
9	-0.36000000E 01	0.40065298E-04	0.	-0.72000000E 01	0.12771116E-09	0.
10	-0.34875000E 01	0.33546263E-03	0.	-0.69750000E 01	0.15229980E-07	0.
11	-0.33750000E 01	0.21874911E-02	0.	-0.67500000E 01	0.10348542E-05	0.
12	-0.32625000E 01	0.11108997E-01	0.	-0.65250000E 01	0.40065298E-04	0.
13	-0.31500000E 01	0.43936934E-01	0.	-0.63000000E 01	0.88382636E-03	0.
14	-0.30375000E 01	0.13533529E 00	0.	-0.60750000E 01	0.11108997E-01	0.
15	-0.29250000E 01	0.32465247E 00	0.	-0.58500000E 01	0.79559509E-01	0.
16	-0.28125000E 01	0.60653067E 00	0.	-0.56250000E 01	0.32465247E 00	0.
17	-0.27000000E 01	0.88249690E 00	0.	-0.54000000E 01	0.75483961E 00	0.
18	-0.25875000E 01	0.10000000E 01	0.	-0.51750000E 01	0.10000000E 01	0.
19	-0.24750000E 01	0.10000000E 01	0.	-0.49500000E 01	0.10000000E 01	0.
20	-0.23625000E 01	0.10000000E 01	0.	-0.47250000E 01	0.10000000E 01	0.
21	-0.22500000E 01	0.10000000E 01	0.	-0.45000000E 01	0.10000000E 01	0.
22	-0.21375000E 01	0.10000000E 01	0.	-0.42750000E 01	0.10000000E 01	0.
23	-0.20250000E 01	0.10000000E 01	0.	-0.40500000E 01	0.10000000E 01	0.
24	-0.19125000E 01	0.10000000E 01	0.	-0.38250000E 01	0.10000000E 01	0.
25	-0.18000000E 01	0.10000000E 01	0.	-0.36000000E 01	0.10000000E 01	0.
26	-0.16875000E 01	0.10000000E 01	0.	-0.33750000E 01	0.10000000E 01	0.
27	-0.15750000E 01	0.10000000E 01	0.	-0.31500000E 01	0.10000000E 01	0.
28	-0.14625000E 01	0.10000000E 01	0.	-0.29250000E 01	0.10000000E 01	0.
29	-0.13500000E 01	0.10000000E 01	0.	-0.27000000E 01	0.10000000E 01	0.
30	-0.12375000E 01	0.10000000E 01	0.	-0.24750000E 01	0.10000000E 01	0.
31	-0.11250000E 01	0.10000000E 01	0.	-0.22500000E 01	0.10000000E 01	0.
32	-0.10125000E 01	0.10000000E 01	0.	-0.20250000E 01	0.10000000E 01	0.
33	-0.90000000E 00	0.10000000E 01	0.	-0.18000000E 01	0.10000000E 01	0.
34	-0.78750000E 00	0.10000000E 01	0.	-0.15750000E 01	0.10000000E 01	0.
35	-0.67500000E 00	0.10000000E 01	0.	-0.13500000E 01	0.10000000E 01	0.
36	-0.56250000E 00	0.10000000E 01	0.	-0.11250000E 01	0.10000000E 01	0.
37	-0.45000000E 00	0.10000000E 01	0.	-0.90000000E 00	0.10000000E 01	0.
38	-0.33750000E 00	0.10000000E 01	0.	-0.67500000E 00	0.10000000E 01	0.
39	-0.22500000E 00	0.10000000E 01	0.	-0.45000000E 00	0.10000000E 01	0.
40	-0.11250000E 00	0.10000000E 01	0.	-0.22500000E 00	0.10000000E 01	0.
41	0.	0.10000000E 01	0.	0.	0.10000000E 01	0.
42	0.11250000E 00	0.10000000E 01	0.	0.22500000E 00	0.10000000E 01	0.
43	0.22500000E 00	0.10000000E 01	0.	0.45000000E 00	0.10000000E 01	0.
44	0.33750000E 00	0.10000000E 01	0.	0.67500000E 00	0.10000000E 01	0.
45	0.45000000E 00	0.10000000E 01	0.	0.90000000E 00	0.10000000E 01	0.
46	0.56250000E 00	0.10000000E 01	0.	0.11250000E 01	0.10000000E 01	0.
47	0.67500000E 00	0.10000000E 01	0.	0.13500000E 01	0.10000000E 01	0.
48	0.78750000E 00	0.10000000E 01	0.	0.15750000E 01	0.10000000E 01	0.
49	0.90000000E 00	0.10000000E 01	0.	0.18000000E 01	0.10000000E 01	0.
50	0.10125000E 01	0.10000000E 01	0.	0.20250000E 01	0.10000000E 01	0.

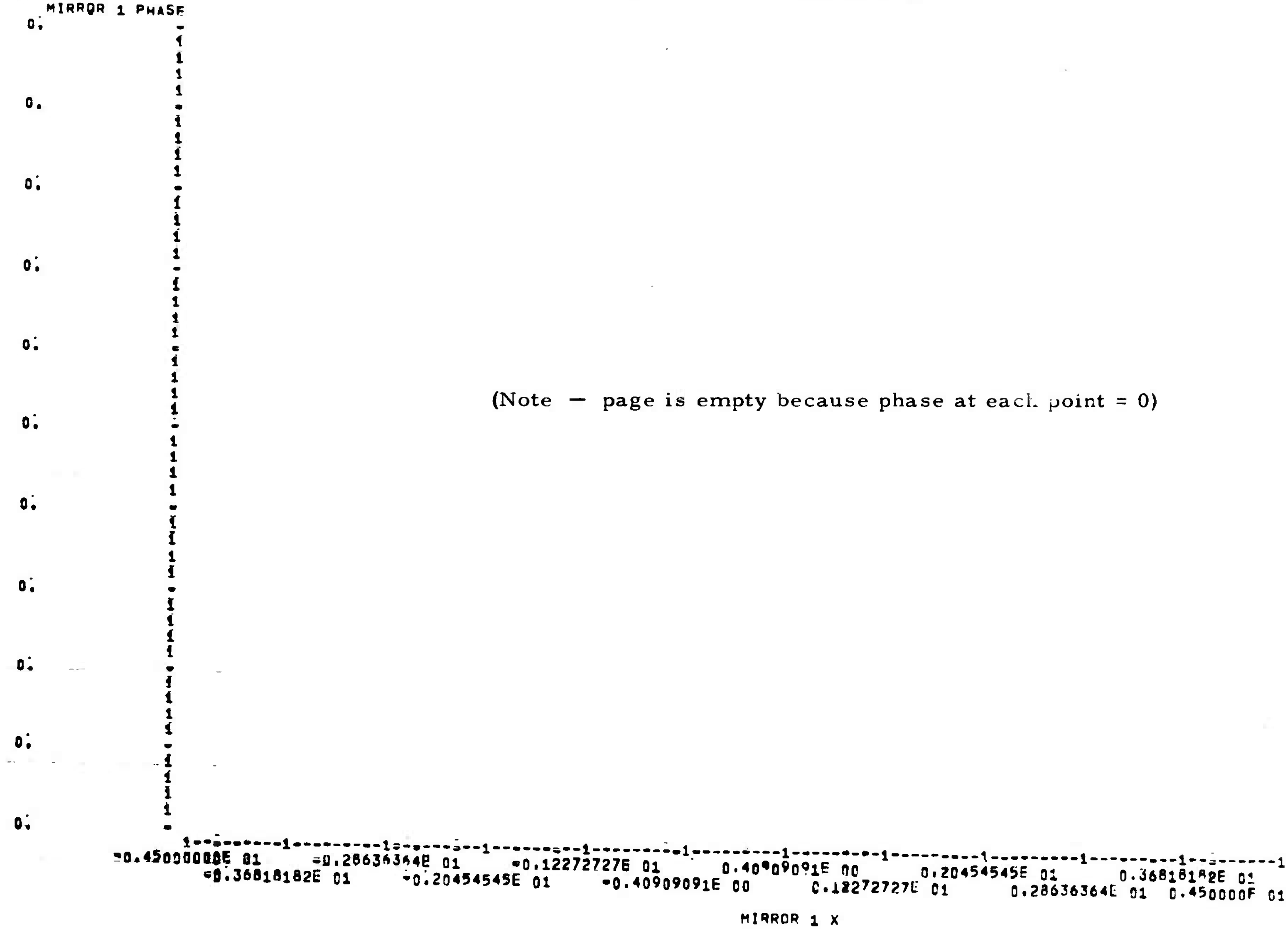
MIRROR DESCRIPTIONS

I	MIRROR 1 X	MIRROR 1 INT	MIRROR 1 PHASE	MIRROR 2 X	MIRROR 2 INT	MIRROR 2 PHASE
51	0.11250000E 01	0.10000000E 01	0.	0.22500000E 01	0.10000000E 01	0.
52	0.12375000E 01	0.10000000E 01	0.	0.24750000E 01	0.10000000E 01	0.
53	0.13500000E 01	0.10000000E 01	0.	0.27000000E 01	0.10000000E 01	0.
54	0.14625000E 01	0.10000000E 01	0.	0.29250000E 01	0.10000000E 01	0.
55	0.15750000E 01	0.10000000E 01	0.	0.31500000E 01	0.10000000E 01	0.
56	0.16875000E 01	0.10000000E 01	0.	0.33750000E 01	0.10000000E 01	0.
57	0.18000000E 01	0.10000000E 01	0.	0.36000000E 01	0.10000000E 01	0.
58	0.19125000E 01	0.10000000E 01	0.	0.38250000E 01	0.10000000E 01	0.
59	0.20250000E 01	0.10000000E 01	0.	0.40500000E 01	0.10000000E 01	0.
60	0.21375000E 01	0.10000000E 01	0.	0.42750000E 01	0.10000000E 01	0.
61	0.22500000E 01	0.10000000E 01	0.	0.45000000E 01	0.10000000E 01	0.
62	0.23625000E 01	0.10000000E 01	0.	0.47250000E 01	0.10000000E 01	0.
63	0.24750000E 01	0.10000000E 01	0.	0.49500000E 01	0.10000000E 01	0.
64	0.25875000E 01	0.10000000E 01	0.	0.51750000E 01	0.10000000E 01	0.
65	0.27000000E 01	0.88249690E 00	0.	0.54000000E 01	0.75483961E 00	0.
66	0.28125000E 01	0.60653067E 00	0.	0.56250000E 01	0.32465247E 00	0.
67	0.29250000E 01	0.32465247E 00	0.	0.58500000E 01	0.79559509E-01	0.
68	0.30375000E 01	0.13533529E 00	0.	0.60750000E 01	0.11108997E-01	0.
69	0.31500000E 01	0.43936934E-01	0.	0.63000000E 01	0.88382636E-03	0.
70	0.32625000E 01	0.11108997E-01	0.	0.65250000E 01	0.40065298E-04	0.
71	0.33750000E 01	0.21874911E-02	0.	0.67500000E 01	0.10348542E-05	0.
72	0.34875000E 01	0.33546263E-03	0.	0.69750000E 01	0.15229980E-07	0.
73	0.36000000E 01	0.40065298E-04	0.	0.72000000E 01	0.12771116E-09	0.
74	0.37125000E 01	0.37266532E-05	0.	0.74250000E 01	0.61019381E-12	0.
75	0.38250000E 01	0.26995786E-06	0.	0.76500000E 01	0.16611770E-14	0.
76	0.39375000E 01	0.15229980E-07	0.	0.78750000E 01	0.25767571E-17	0.
77	0.40500000E 01	0.66915861E-09	0.	0.81000000E 01	0.22774057E-20	0.
78	0.41625000E 01	0.22697348E-10	0.	0.83249999E 01	0.11468766E-23	0.
79	0.42750000E 01	0.61019367E-12	0.	0.85500000E 01	0.32906078E-27	0.
80	0.43875000E 01	0.12664166E-13	0.	0.87750000E 01	0.53801861E-31	0.
81	0.45000000E 01	0.20469717E-15	0.	0.96000000E 01	0.50118913E-35	0.

MIRROR DESCRIPTIONS
NUMBER OF POINTS= 81 X INCREMENT= 0.81818182E-01 Y INCREMENT= 0.20000000E-01

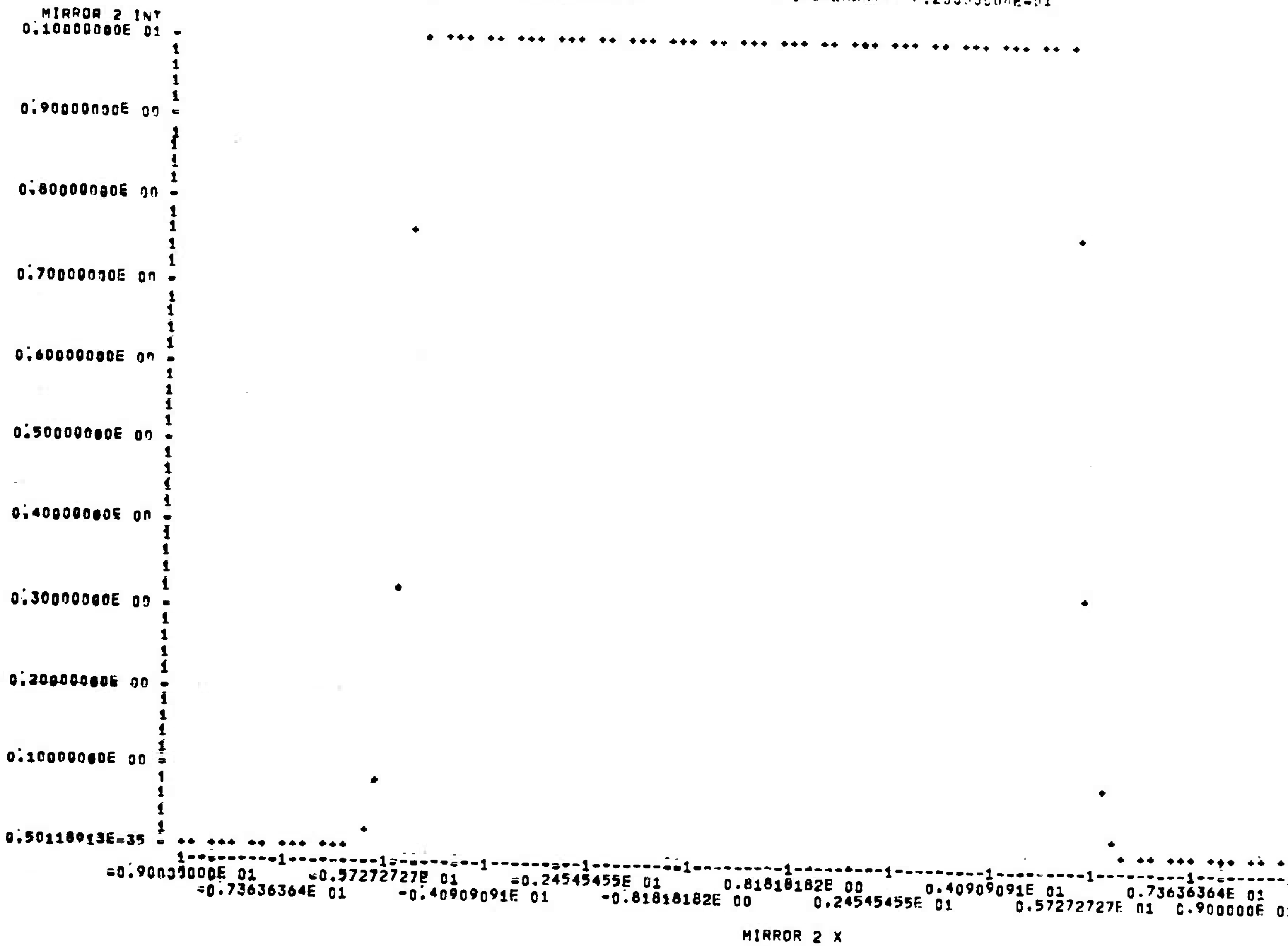


MIRROR DESCRIPTIONS
NUMBER OF POINTS= 81 X INCREMENT= 0.81818182E-01 Y INCREMENT= 0.

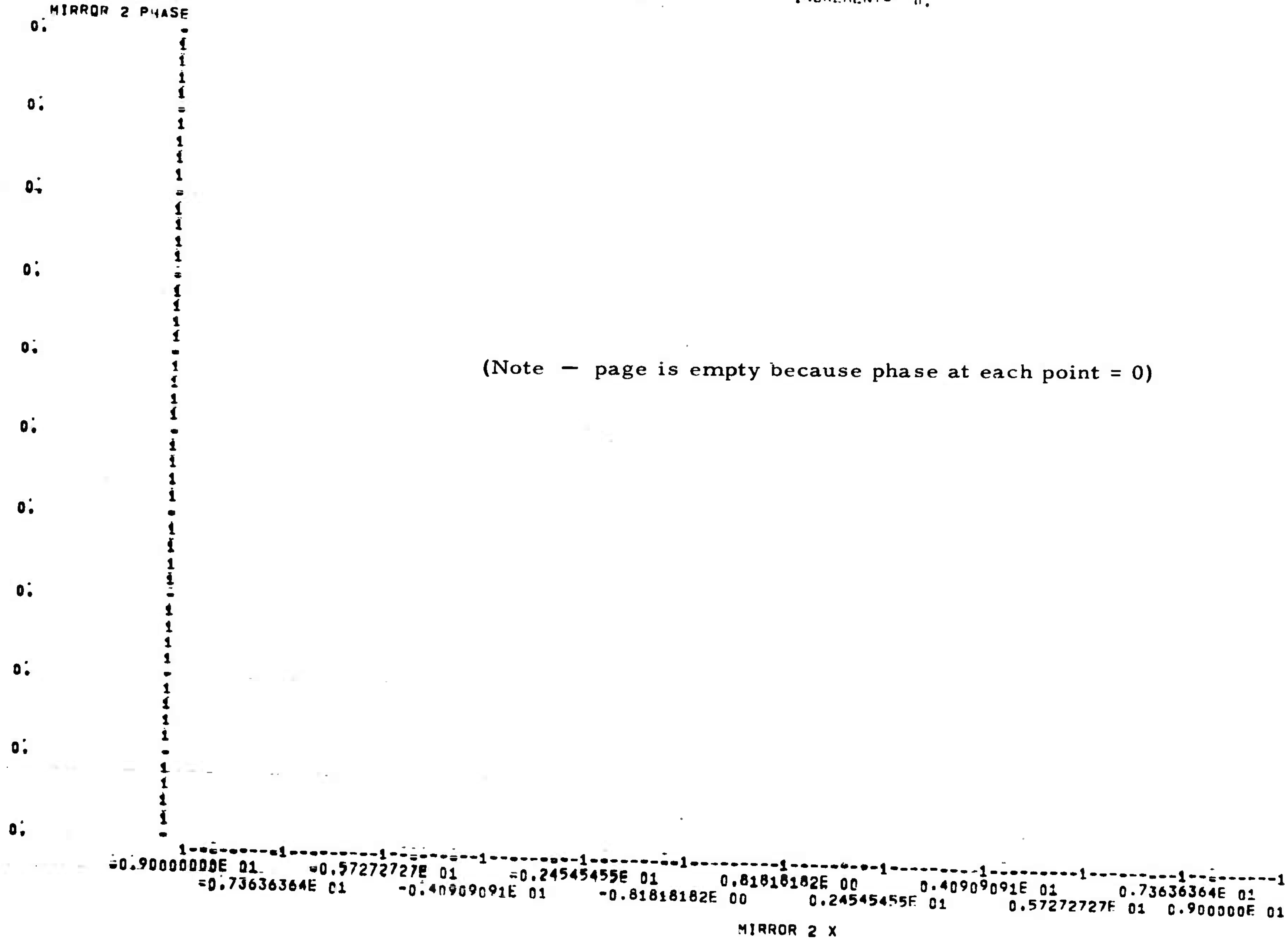


MIRROR DESCRIPTIONS
NUMBER OF POINTS= 81

X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.20000000E-01



MIRROR DESCRIPTIONS
NUMBER OF POINTS= 81 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.

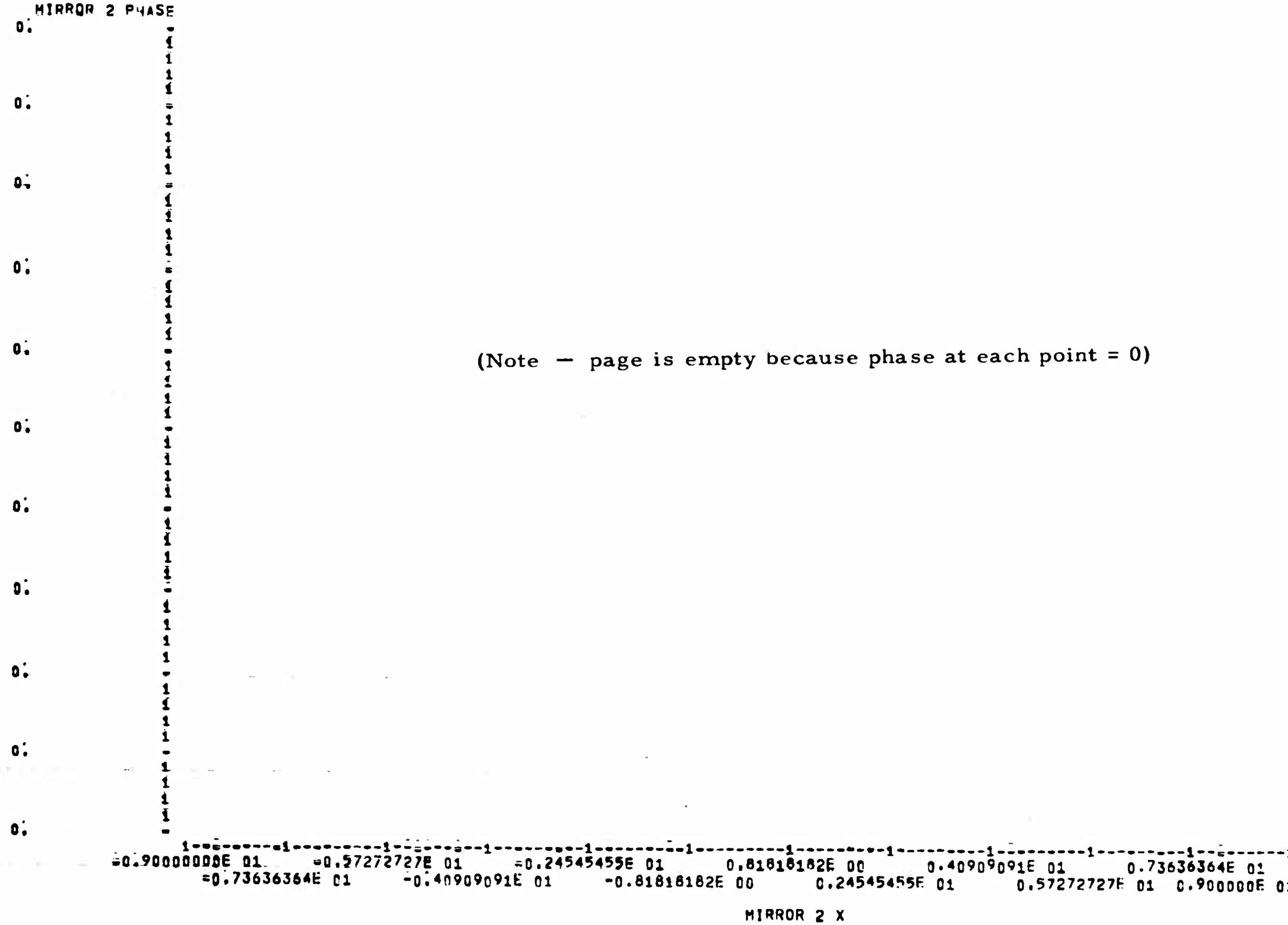


(Note — page is empty because phase at each point = 0)

INPUT WAVE DESCRIPTION

I	X	MAGNITUDE	INTENSITY	PHASE (DG)	NORM AREA
1	-0.90000000E 01	0.	0.	-0.50000000E 00	0.10000000E 01
2	-0.87750000E 01	0.10000000E 01	0.10000000E 01	0.	0.97468355E 00
3	-0.85500000E 01	0.10000000E 01	0.10000000E 01	0.	0.94936709E 00
4	-0.83249999E 01	0.10000000E 01	0.10000000E 01	0.	0.92405064E 00
5	-0.81000000E 01	0.10000000E 01	0.10000000E 01	0.	0.89873417E 00
6	-0.78750000E 01	0.10000000E 01	0.10000000E 01	0.	0.87341772E 00
7	-0.76500000E 01	0.10000000E 01	0.10000000E 01	0.	0.84810127E 00
8	-0.74250000E 01	0.10000000E 01	0.10000000E 01	0.	0.82278481E 00
9	-0.72000000E 01	0.10000000E 01	0.10000000E 01	0.	0.79746836E 00
10	-0.69750000E 01	0.10000000E 01	0.10000000E 01	0.	0.77215190E 00
11	-0.67500000E 01	0.10000000E 01	0.10000000E 01	0.	0.74683544E 00
12	-0.65250000E 01	0.10000000E 01	0.10000000E 01	0.	0.72151899E 00
13	-0.63000000E 01	0.10000000E 01	0.10000000E 01	0.	0.69620253E 00
14	-0.60750000E 01	0.10000000E 01	0.10000000E 01	0.	0.67088608E 00
15	-0.58500000E 01	0.10000000E 01	0.10000000E 01	0.	0.64556962E 00
16	-0.56250000E 01	0.10000000E 01	0.10000000E 01	0.	0.62025317E 00
17	-0.54000000E 01	0.10000000E 01	0.10000000E 01	0.	0.59493671E 00
18	-0.51750000E 01	0.10000000E 01	0.10000000E 01	0.	0.56962025E 00
19	-0.49500000E 01	0.10000000E 01	0.10000000E 01	0.	0.54430380E 00
20	-0.47250000E 01	0.10000000E 01	0.10000000E 01	0.	0.51898734E 00
21	-0.45000000E 01	0.10000000E 01	0.10000000E 01	0.	0.49367088E 00
22	-0.42750000E 01	0.10000000E 01	0.10000000E 01	0.	0.46835443E 00
23	-0.40500000E 01	0.10000000E 01	0.10000000E 01	0.	0.44303798E 00
24	-0.38250000E 01	0.10000000E 01	0.10000000E 01	0.	0.41772152E 00
25	-0.36000000E 01	0.10000000E 01	0.10000000E 01	0.	0.39240506E 00
26	-0.33750000E 01	0.10000000E 01	0.10000000E 01	0.	0.36708861E 00
27	-0.31500000E 01	0.10000000E 01	0.10000000E 01	0.	0.34177215E 00
28	-0.29250000E 01	0.10000000E 01	0.10000000E 01	0.	0.31645570E 00
29	-0.27000000E 01	0.10000000E 01	0.10000000E 01	0.	0.29113924E 00
30	-0.24750000E 01	0.10000000E 01	0.10000000E 01	0.	0.26582278E 00
31	-0.22500000E 01	0.10000000E 01	0.10000000E 01	0.	0.24050633E 00
32	-0.20250000E 01	0.10000000E 01	0.10000000E 01	0.	0.21518987E 00
33	-0.18000000E 01	0.10000000E 01	0.10000000E 01	0.	0.18987342E 00
34	-0.15750000E 01	0.10000000E 01	0.10000000E 01	0.	0.16455696E 00
35	-0.13500000E 01	0.10000000E 01	0.10000000E 01	0.	0.13924051E 00
36	-0.11250000E 01	0.10000000E 01	0.10000000E 01	0.	0.11392405E 00
37	-0.90000000E 00	0.10000000E 01	0.10000000E 01	0.	0.88607595E-01
38	-0.67500000E 00	0.10000000E 01	0.10000000E 01	0.	0.63291139E-01
39	-0.45000000E 00	0.10000000E 01	0.10000000E 01	0.	0.37974684E-01
40	-0.22500000E 00	0.10000000E 01	0.10000000E 01	0.	0.12658228E-01
41	0.	0.10000000E 01	0.10000000E 01	0.	0.12658228E-01
42	0.22500000E 00	0.10000000E 01	0.10000000E 01	0.	0.37974684E-01
43	0.45000000E 00	0.10000000E 01	0.10000000E 01	0.	0.63291139E-01
44	0.67500000E 00	0.10000000E 01	0.10000000E 01	0.	0.88607595E-01
45	0.90000000E 00	0.10000000E 01	0.10000000E 01	0.	0.11392405E 00
46	0.11250000E 01	0.10000000E 01	0.10000000E 01	0.	0.13924051E 00
47	0.13500000E 01	0.10000000E 01	0.10000000E 01	0.	0.16455696E 00
48	0.15750000E 01	0.10000000E 01	0.10000000E 01	0.	0.18987342E 00
49	0.18000000E 01	0.10000000E 01	0.10000000E 01	0.	0.21518987E 00
50	0.20250000E 01	0.10000000E 01	0.10000000E 01	0.	0.24050633E 00

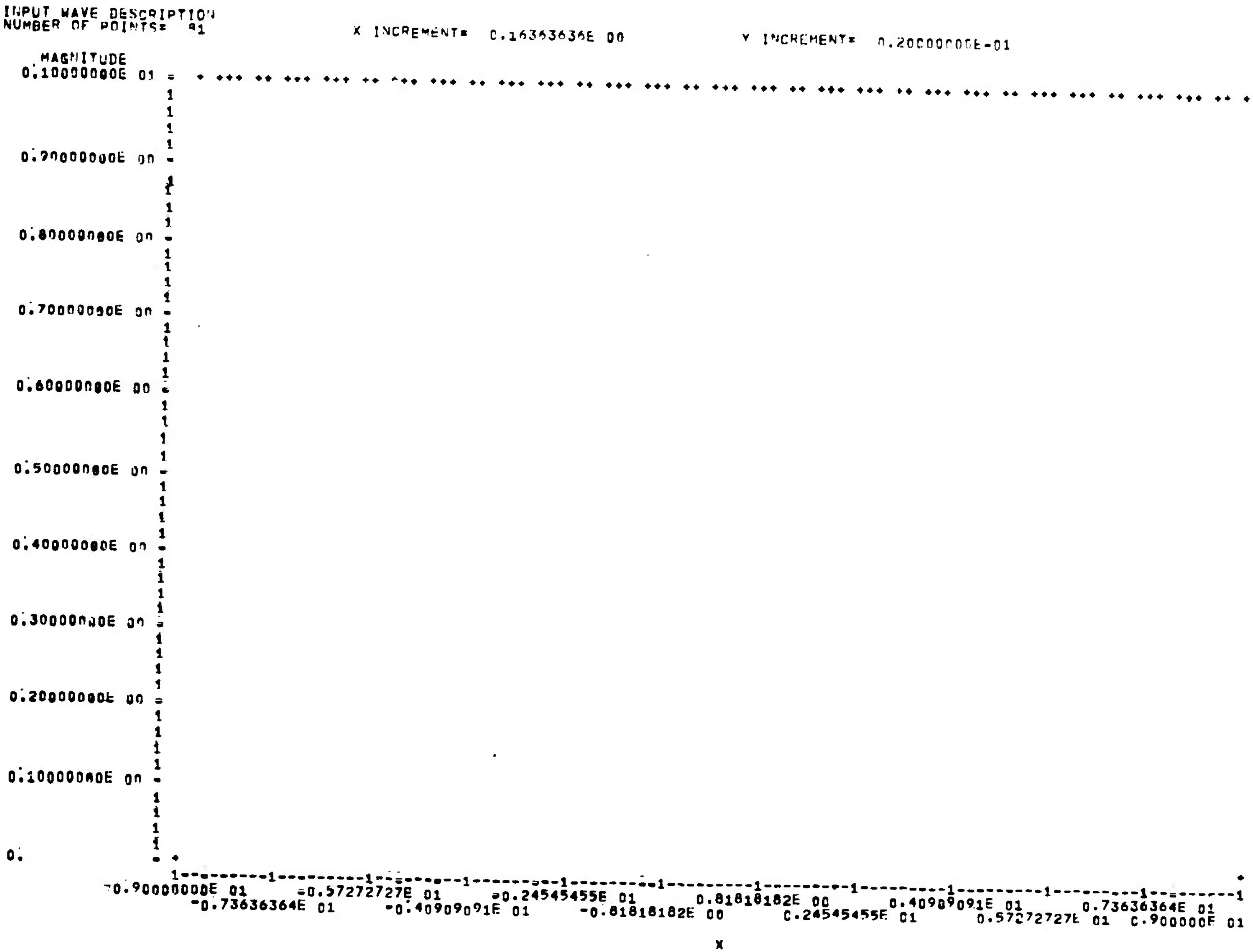
MIRROR DESCRIPTIONS
NUMBER OF POINTS= 81 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.



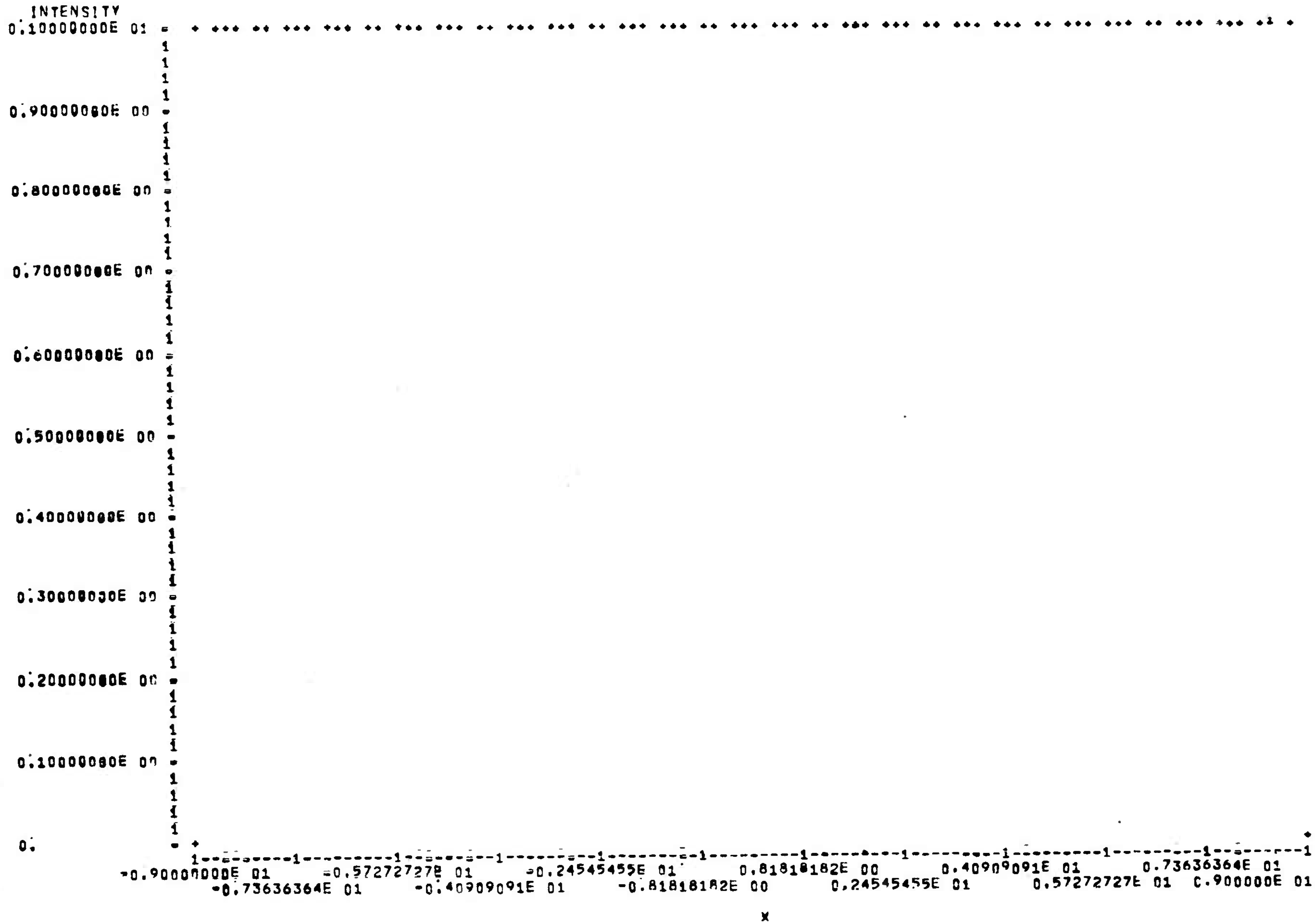
(Note — page is empty because phase at each point = 0)

INPUT WAVE DESCRIPTION

I	X	MAGNITUDE	INTENSITY	PHASE (DG)	NORM AREA
51	0.22500000E 01	0.10000000E 01	0.10000000E 01	0.	0.26582278E 00
52	0.24750000E 01	0.10000000E 01	0.10000000E 01	0.	0.29113924E 00
53	0.27000000E 01	0.10000000E 01	0.10000000E 01	0.	0.31645570E 00
54	0.29250000E 01	0.10000000E 01	0.10000000E 01	0.	0.34177215E 00
55	0.31500000E 01	0.10000000E 01	0.10000000E 01	0.	0.36708861E 00
56	0.33750000E 01	0.10000000E 01	0.10000000E 01	0.	0.39240506E 00
57	0.36000000E 01	0.10000000E 01	0.10000000E 01	0.	0.41772152E 00
58	0.38250000E 01	0.10000000E 01	0.10000000E 01	0.	0.44303798E 00
59	0.40500000E 01	0.10000000E 01	0.10000000E 01	0.	0.46835443E 00
60	0.42750000E 01	0.10000000E 01	0.10000000E 01	0.	0.49367088E 00
61	0.45000000E 01	0.10000000E 01	0.10000000E 01	0.	0.51898734E 00
62	0.47250000E 01	0.10000000E 01	0.10000000E 01	0.	0.54430380E 00
63	0.49500000E 01	0.10000000E 01	0.10000000E 01	0.	0.56962025E 00
64	0.51750000E 01	0.10000000E 01	0.10000000E 01	0.	0.59493671E 00
65	0.54000000E 01	0.10000000E 01	0.10000000E 01	0.	0.62025317E 00
66	0.56250000E 01	0.10000000E 01	0.10000000E 01	0.	0.64556962E 00
67	0.58500000E 01	0.10000000E 01	0.10000000E 01	0.	0.67088608E 00
68	0.60750000E 01	0.10000000E 01	0.10000000E 01	0.	0.69620253E 00
69	0.63000000E 01	0.10000000E 01	0.10000000E 01	0.	0.72151899E 00
70	0.65250000E 01	0.10000000E 01	0.10000000E 01	0.	0.74683544E 00
71	0.67500000E 01	0.10000000E 01	0.10000000E 01	0.	0.77215190E 00
72	0.69750000E 01	0.10000000E 01	0.10000000E 01	0.	0.79746836E 00
73	0.72000000E 01	0.10000000E 01	0.10000000E 01	0.	0.82278481E 00
74	0.74250000E 01	0.10000000E 01	0.10000000E 01	0.	0.84810127E 00
75	0.76500000E 01	0.10000000E 01	0.10000000E 01	0.	0.87341772E 00
76	0.78750000E 01	0.10000000E 01	0.10000000E 01	0.	0.89873417E 00
77	0.81000000E 01	0.10000000E 01	0.10000000E 01	0.	0.92405064E 00
78	0.83249999E 01	0.10000000E 01	0.10000000E 01	0.	0.94936709E 00
79	0.85500000E 01	0.10000000E 01	0.10000000E 01	0.	0.97468355E 00
80	0.87750000E 01	0.10000000E 01	0.10000000E 01	0.	0.10000000E 01
81	0.90000000E 01	0.	0.	-0.50000000E 00	0.10000000E 01

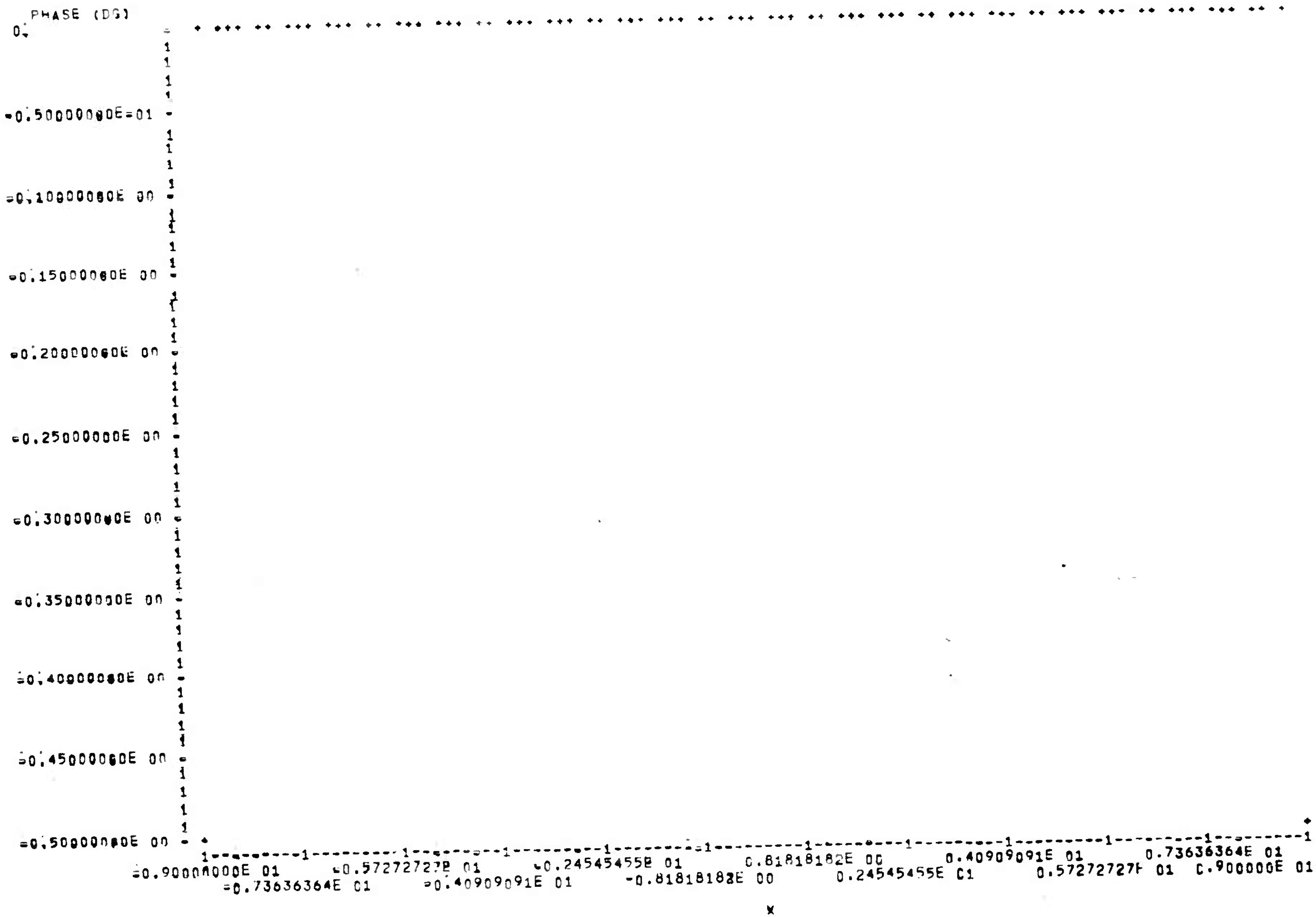

INPUT WAVE DESCRIPTION
NUMBER OF POINTS= 91
X INCREMENT= 0.16363636E 00
Y INCREMENT= 0.20000000E-01
MAGNITUDE
0.10000000E 01
0.90000000E 00
0.80000000E 00
0.70000000E 00
0.60000000E 00
0.50000000E 00
0.40000000E 00
0.30000000E 00
0.20000000E 00
0.10000000E 00
0.
-0.90000000E 01
-0.73636364E 01
-0.57272727E 01
-0.40909091E 01
-0.24545455E 01
-0.81818182E 00
0.81818182E 00
0.24545455E 01
0.40909091E 01
0.57272727E 01
0.73636364E 01
0.900000E 01
X

INPUT WAVE DESCRIPTION
NUMBER OF POINTS= 81   X INCREMENT= 0.16363636E 00   Y INCREMENT= 0.20000000E-01

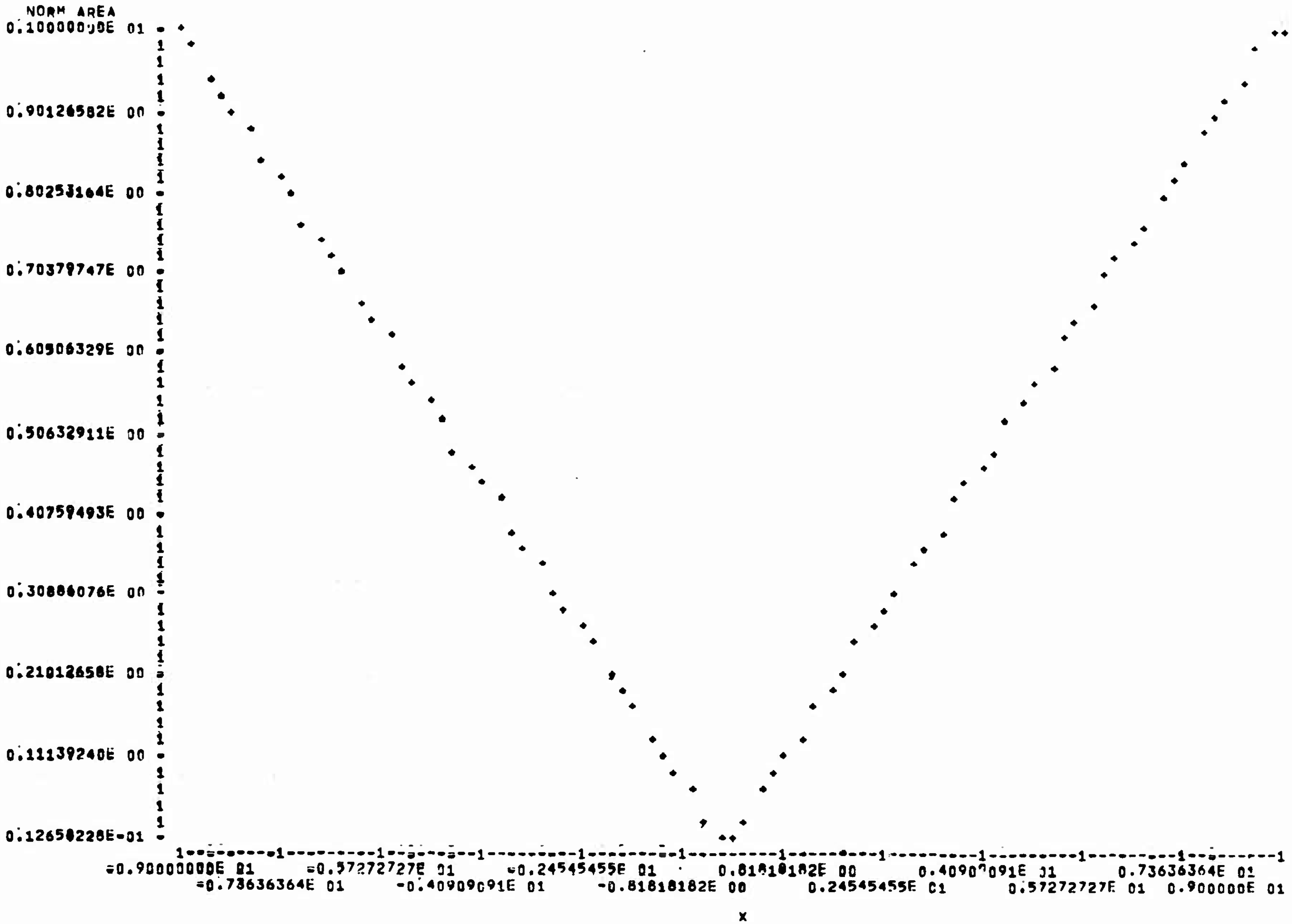


INPUT WAVE DESCRIPTION
NUMBER OF POINTS= 81

X INCREMENT= 0.16363636E 05   Y INCREMENT= 0.10000000E-01



INPUT WAVE DESCRIPTION
NUMBER OF POINTS= 81 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.19746835E-01



POWER

```
STARTING PASS NUMBER     1 FOR CASE    8.45

AREA(S) AT START OF PASS
    2D AREA          0.1777500E 02

AFTER INTERPOLATION
    2D AREA          0.9112500E 01

AFTER OUTPUT MIRROR
    2D AREA          0.5738991E 01

AFTER STEP-BY-STEP PROPAGATION
    2D AREA          0.5736809E 01

AFTER MEDIUM
    2D AREA          0.3208506E 02

AFTER STEP-BY-STEP PROPAGATION
    2D AREA          0.3207932E 02

AFTER BACK MIRROR
    2D AREA          0.3014538E 02

AFTER STEP-BY-STEP PROPAGATION
    2D AREA          0.3014541E 02

AFTER MEDIUM
    2D AREA          0.1516768E 03

AFTER STEP-BY-STEP PROPAGATION
    2D AREA          0.1516770E 03

FINISHED PASS NUMBER     1

POWER
    NEAR FIELD POWER=        0.1516770E 03
    OUTPUT POWER AFTER MIRROR=        0.6655180E 02
    POWER DIFFERENCE=        0.8512518E 02
```

```
NEAR FIELD POWER=        0.1777500E 02
OUTPUT POWER AFTER MIRROR=        0.6750000E 01
POWER DIFFERENCE=        0.1102500E 02
```

N.F. RESULTS FOR ROUND TRIP

I	X	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
1	-0.90000000E 01	0.	0.	0.	0.	-0.47777588E 00	0.10000000E 01
2	-0.87750000E 01	0.27509028E-02	0.75674660E-05	0.65972590E-03	0.43523826E-06	-0.16795838E 01	0.99999998E 00
3	-0.85500000E 01	0.64548812E-02	0.41665491E-04	0.15480199E-02	0.23963657E-05	-0.27730102E 01	0.99999985E 00
4	-0.83249999E 01	0.15658258E-01	0.24518104E-03	0.37551884E-02	0.14101440E-04	0.23280790E 01	0.99999913E 00
5	-0.81000000E 01	0.35372425E-01	0.12512085E-02	0.84830717E-02	0.71962505E-04	0.11844966E 01	0.99999542E 00
6	-0.78750000E 01	0.73454179E-01	0.53955163E-02	0.17615899E-01	0.31031989E-03	0.60758909E-01	0.99997941E 00
7	-0.76500000E 01	0.13848146E 00	0.19177114E-01	0.33210845E-01	0.11029602E-02	-0.10336991E 01	0.99992251E 00
8	-0.74250000E 01	0.23311353E 00	0.54341917E-01	0.55905659E-01	0.31254427E-02	-0.20827176E 01	0.99976129E 00
9	-0.72000000E 01	0.34559516E 00	0.11943601E 00	0.82881184E-01	0.68692907E-02	-0.30560904E 01	0.99940694E 00
10	-0.69750000E 01	0.45262854E 00	0.20487260E 00	0.10855010E 00	0.11783124E-01	0.23792399E 01	0.99879912E 00
11	-0.67500000E 01	0.55193912E 00	0.30463679E 00	0.13236692E 00	0.17521002E-01	0.17093095E 01	0.99789532E 00
12	-0.65250000E 01	0.68599200E 00	0.47058502E 00	0.16451570E 00	0.27065415E-01	0.11938324E 01	0.99649917E 00
13	-0.63000000E 01	0.86683653E 00	0.75140557E 00	0.20788612E 00	0.43216641E-01	0.75069033E 00	0.99426987E 00
14	-0.60750000E 01	0.10668536E 01	0.11381766E 01	0.25585454E 00	0.65461545E-01	0.38988602E 00	0.99089310E 00
15	-0.58500000E 01	0.13157222E 01	0.17311248E 01	0.31553859E 00	0.99564604E-01	0.12020755E 00	0.98575714E 00
16	-0.56250000E 01	0.16160268E 01	0.26115426E 01	0.38755813E 00	0.15020131E 00	-0.87969847E-01	0.97800913E 00
17	-0.54000000E 01	0.19598068E 01	0.38408426E 01	0.47000400E 00	0.22090376E 00	-0.22880246E 00	0.96661400E 00
18	-0.51750000E 01	0.23557822E 01	0.55497097E 01	0.56496745E 00	0.31918823E 00	-0.31356803E 00	0.95014695E 00
19	-0.49500000E 01	0.27804054E 01	0.77306541E 01	0.66680127E 00	0.44462393E 00	-0.34864053E 00	0.92721341E 00
20	-0.47250000E 01	0.32097746E 01	0.10302654E 02	0.76977332E 00	0.59255096E 00	-0.33791273E 00	0.89664717E 00
21	-0.45000000E 01	0.36072430E 01	0.13012202E 02	0.86509479E 00	0.74838899E 00	-0.29345783E 00	0.85804217E 00
22	-0.42750000E 01	0.39249308E 01	0.15405882E 02	0.94128319E 00	0.88601404E 00	-0.22094188E 00	0.81233789E 00
23	-0.40500000E 01	0.41129022E 01	0.16915964E 02	0.98636278E 00	0.97291153E 00	-0.14274439E 00	0.76215108E 00
24	-0.38250000E 01	0.41697662E 01	0.17386950E 02	0.10000000E 01	0.10000000E 01	-0.68059354E-01	0.71056693E 00
25	-0.36000000E 01	0.41108785E 01	0.16899323E 02	0.98587747E 00	0.97195440E 00	-0.21498526E-01	0.66042949E 00
26	-0.33750000E 01	0.40759143E 01	0.16613077E 02	0.97749228E 00	0.95549117E 00	-0.36995076E-02	0.61114130E 00
27	-0.31500000E 01	0.41017292E 01	0.16824183E 02	0.98368327E 00	0.96763278E 00	0.30448369E-01	0.56122679E 00
28	-0.29250000E 01	0.40437399E 01	0.16351832E 02	0.96977618E 00	0.94046583E 00	0.76080858E-01	0.51271366E 00
29	-0.27000000E 01	0.38830748E 01	0.15078270E 02	0.93124521E 00	0.86721764E 00	0.99128339E-01	0.46797698E 00
30	-0.24750000E 01	0.37153394E 01	0.13803747E 02	0.89101864E 00	0.79391422E 00	0.94909007E-01	0.42702559E 00
31	-0.22500000E 01	0.35902767E 01	0.12890086E 02	0.86102589E 00	0.74136559E 00	0.71029679E-01	0.38878288E 00
32	-0.20250000E 01	0.35358564E 01	0.12502281E 02	0.84797475E 00	0.71906117E 00	0.35667561E-01	0.35169072E 00
33	-0.18000000E 01	0.35661085E 01	0.12717130E 02	0.85522984E 00	0.73141808E 00	0.27358464E-02	0.31396115E 00
34	-0.15750000E 01	0.36697375E 01	0.13466974E 02	0.88008233E 00	0.77454491E 00	-0.16092720E-01	0.27400691E 00
35	-0.13500000E 01	0.37823790E 01	0.14306391E 02	0.90709619E 00	0.82282350E 00	-0.15343439E-01	0.23156227E 00
36	-0.11250000E 01	0.38315929E 01	0.14681104E 02	0.91889873E 00	0.84437488E 00	0.22406061E-02	0.18800591E 00
37	-0.90000000E 00	0.38218368E 01	0.14606437E 02	0.91655903E 00	0.84008045E 00	0.31908810E-01	0.14467108E 00
38	-0.67500000E 00	0.37901863E 01	0.14365512E 02	0.90896853E 00	0.82622380E 00	0.51736911E-01	0.10205103E 00
39	-0.45000000E 00	0.37481548E 01	0.14048664E 02	0.89888848E 00	0.80800050E 00	0.39518535E-01	0.60371014E-01
40	-0.22500000E 00	0.36934200E 01	0.13641351E 02	0.88576189E 00	0.78457413E 00	0.12369751E-01	0.19899433E-01
41	0.	0.36625979E 01	0.13414623E 02	0.87837010E 00	0.77153403E 00	0.	0.19899489E-01
42	0.22500000E 00	0.36934199E 01	0.13641351E 02	0.88576188E 00	0.78457411E 00	0.12369800E-01	0.60371071E-01
43	0.45000000E 00	0.37481548E 01	0.14048665E 02	0.89888848E 00	0.80800051E 00	0.39518549E-01	0.10205108E 00
44	0.67500000E 00	0.37901863E 01	0.14365513E 02	0.90896855E 00	0.82622384E 00	0.51736919E-01	0.14467114E 00
45	0.90000000E 00	0.38218370E 01	0.14606438E 02	0.91655907E 00	0.84008052E 00	0.31908789E-01	0.18800597E 00
46	0.11250000E 01	0.38315929E 01	0.14681105E 02	0.91889875E 00	0.84437492E 00	0.22406136E-02	0.23156232E 00
47	0.13500000E 01	0.37823791E 01	0.14306392E 02	0.90709621E 00	0.82282353E 00	-0.15343482E-01	0.27400697E 00
48	0.15750000E 01	0.36697374E 01	0.13466972E 02	0.88008229E 00	0.77454484E 00	-0.16092743E-01	0.31396121E 00
49	0.18000000E 01	0.35661064E 01	0.12717129E 02	0.85522983E 00	0.73141807E 00	0.27358655E-02	0.35169078E 00
50	0.20250000E 01	0.35358564E 01	0.12502280E 02	0.84797474E 00	0.71906116E 00	0.35667559E-01	0.38878294E 00

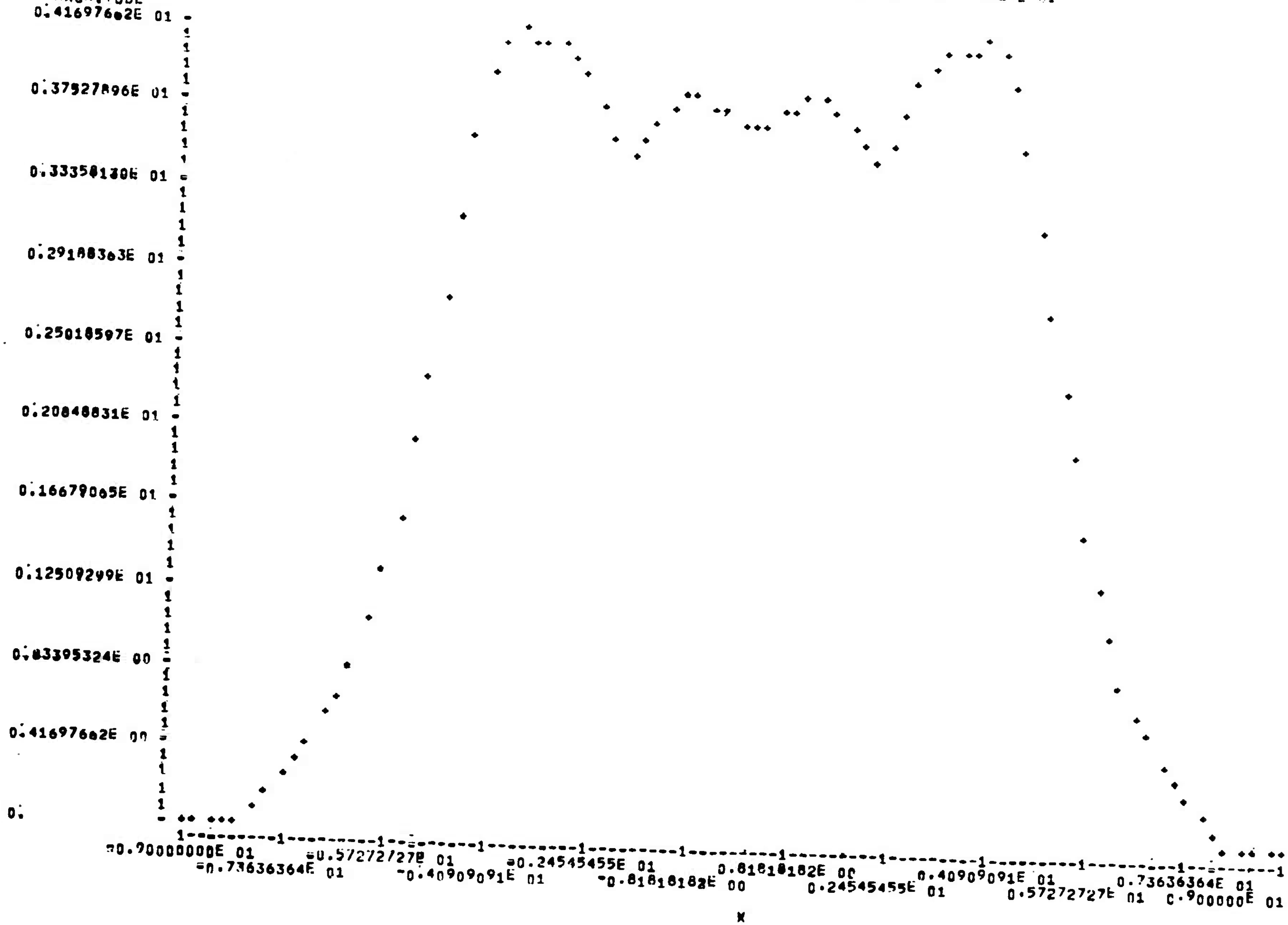
N.F. RESULTS FOR ROUND TRIP

I	X	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
51	0.22500000E 01	0.35902766E 01	0.12890086E 02	0.86102588E 00	0.74136557E 00	0.71029657E-01	0.42702565E 00
52	0.24750000E 01	0.37153394E 01	0.13803747E 02	0.89101564E 00	0.79391423E 00	0.94909009E-01	0.46797903E 00
53	0.27000000E 01	0.38830749E 01	0.15078271E 02	0.93124523E 00	0.86721768E 00	0.99128383E-01	0.51271372E 00
54	0.29250000E 01	0.40437399E 01	0.16351832E 02	0.96977618E 00	0.94046583E 00	0.76080848E-01	0.56122683E 00
55	0.31500000E 01	0.41017293E 01	0.16824184E 02	0.98368330E 00	0.96763283E 00	0.30448292E-01	0.61114133E 00
56	0.33750000E 01	0.40759143E 01	0.16613077E 02	0.97749228E 00	0.95549117E 00	-0.36994833E-02	0.66042952E 00
57	0.36000000E 01	0.41108786E 01	0.16899323E 02	0.98587750E 00	0.97195445E 00	-0.21498562E-01	0.71056896E 00
58	0.38250000E 01	0.41697661E 01	0.17386949E 02	0.99999997E 00	0.99999995E 00	-0.68059327E-01	0.76215110E 00
59	0.40500000E 01	0.41129021E 01	0.16915964E 02	0.98636276E 00	0.97291151E 00	-0.14274442E 00	0.81233791E 00
60	0.42750000E 01	0.39249308E 01	0.15405081E 02	0.94128317E 00	0.88601401E 00	-0.22094188E 00	0.85804218E 00
61	0.45000000E 01	0.36072430E 01	0.13012202E 02	0.86509480E 00	0.74838901E 00	-0.29345781E 00	0.89664718E 00
62	0.47250000E 01	0.32097747E 01	0.10302654E 02	0.76977330E 00	0.59255095E 00	-0.33791273E 00	0.92721340E 00
63	0.49500000E 01	0.27804054E 01	0.77306541E 01	0.66680127E 00	0.44462394E 00	-0.34864048E 00	0.95014694E 00
64	0.51750000E 01	0.23597821E 01	0.55497094E 01	0.56496744E 00	0.31918821E 00	-0.31356800E 00	0.96661401E 00
65	0.54000000E 01	0.19596068E 01	0.38408428E 01	0.47000401E 00	0.22090377E 00	-0.22880240E 00	0.97800913E 00
66	0.56250000E 01	0.16160268E 01	0.26115426E 01	0.38755813E 00	0.15020131E 00	-0.87969853E-01	0.98575714E 00
67	0.58500000E 01	0.13157222E 01	0.173112[illegible]E 01	0.31553860E 00	0.99564610E-01	0.12020763E 00	0.99089310E 00
68	0.60750000E 01	0.10668536E 01	0.11381765E 01	0.25585452E 00	0.65461540E-01	0.38988604E 00	0.99426987E 00
69	0.63000000E 01	0.86683647E 00	0.75140547E 00	0.20788811E 00	0.43216635E-01	0.75069032E 00	0.99649916E 00
70	0.65250000E 01	0.68599201E 00	0.47058503E 00	0.16451570E 00	0.27065416E-01	0.11938324E 01	0.99788132E 00
71	0.67500000E 01	0.55193910E 00	0.30463677E 00	0.13236692E 00	0.17521001E-01	0.17093095E 01	0.99879912E 00
72	0.69750000E 01	0.45262857E 00	0.20487262E 00	0.10855011E 00	0.11783126E-01	0.23792398E 01	0.99940693E 00
73	0.72000000E 01	0.34559521E 00	0.11943605E 00	0.82881196E-01	0.68692928E-02	-0.30560904E 01	0.99976129E 00
74	0.74250000E 01	0.23311357E 00	0.54341938E-01	0.55905670E-01	0.31254440E-02	-0.20827175E 01	0.99992252E 00
75	0.76500000E 01	0.13848148E 00	0.19177119E-01	0.33210849E-01	0.11029603E-02	-0.10336989E 01	0.99997942E 00
76	0.78750000E 01	0.73454181E-01	0.53955167E-02	0.17615899E-01	0.31031991E-03	0.60759141E-01	0.99999543E 00
77	0.81000000E 01	0.35372422E-01	0.12512082E-02	0.84830709E-02	0.71962490E-04	0.11844968E 01	0.99999914E 00
78	0.83249999E 01	0.15658255E-01	0.24518096E-03	0.37551878E-02	0.14101436E-04	0.23280791E 01	0.99999987E 00
79	0.85500000E 01	0.64548797E-02	0.41665472E-04	0.15480196E-02	0.23963646E-05	-0.27730101E 01	0.99999998E 00
80	0.87750000E 01	0.27509023E-02	0.75674633E-05	0.65972579E-03	0.43523811E-06	-0.16795838E 01	0.10000000E 01
81	0.90000000E 01	0.	0.	0.	0.	-0.47777588E 00	0.10000000E 01

N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 81

X INCREMENT= 0.16363636E 00

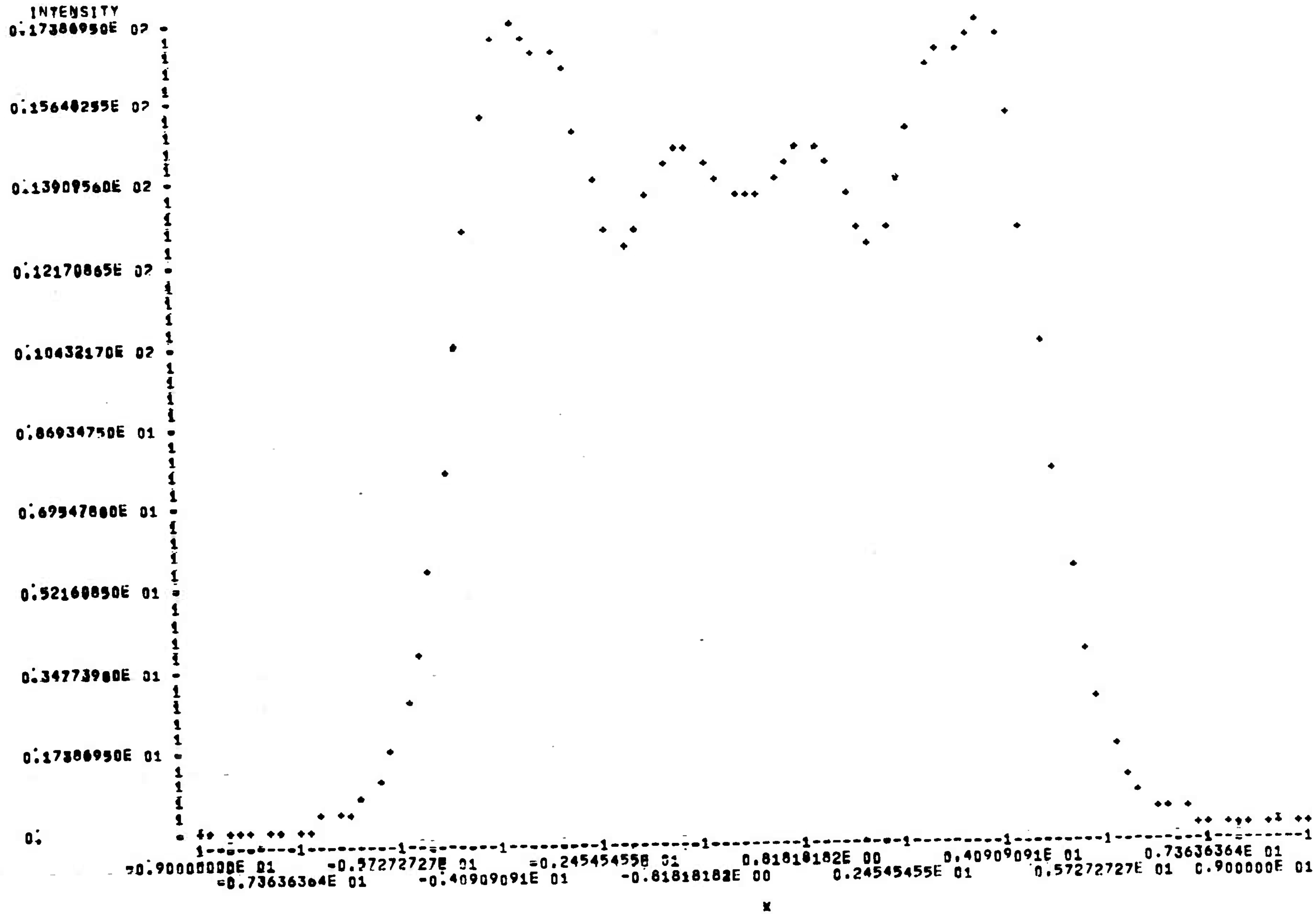
Y INCREMENT= 0.83395324E-01



N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 81

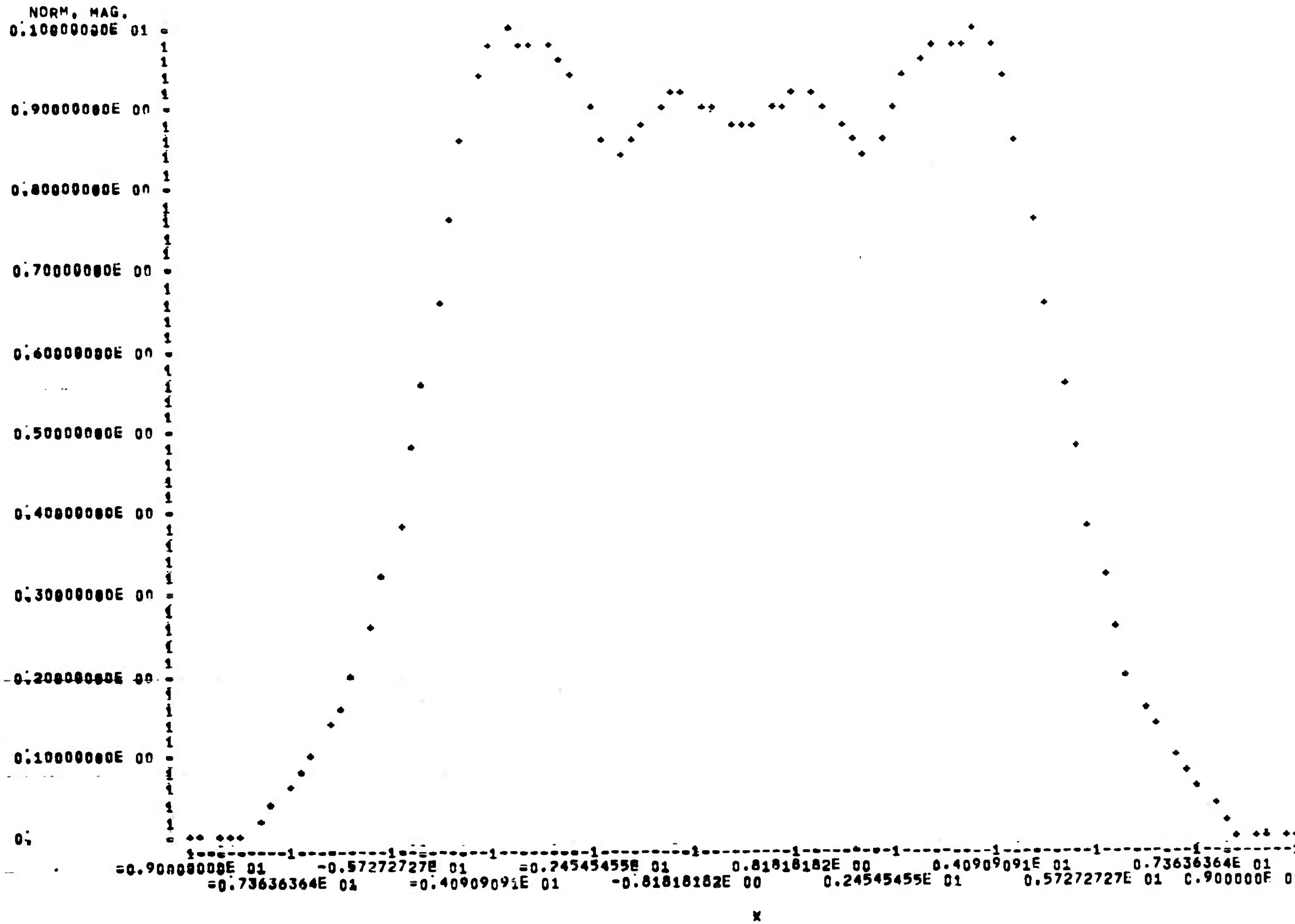
X INCREMENT= 0.16363636E 00

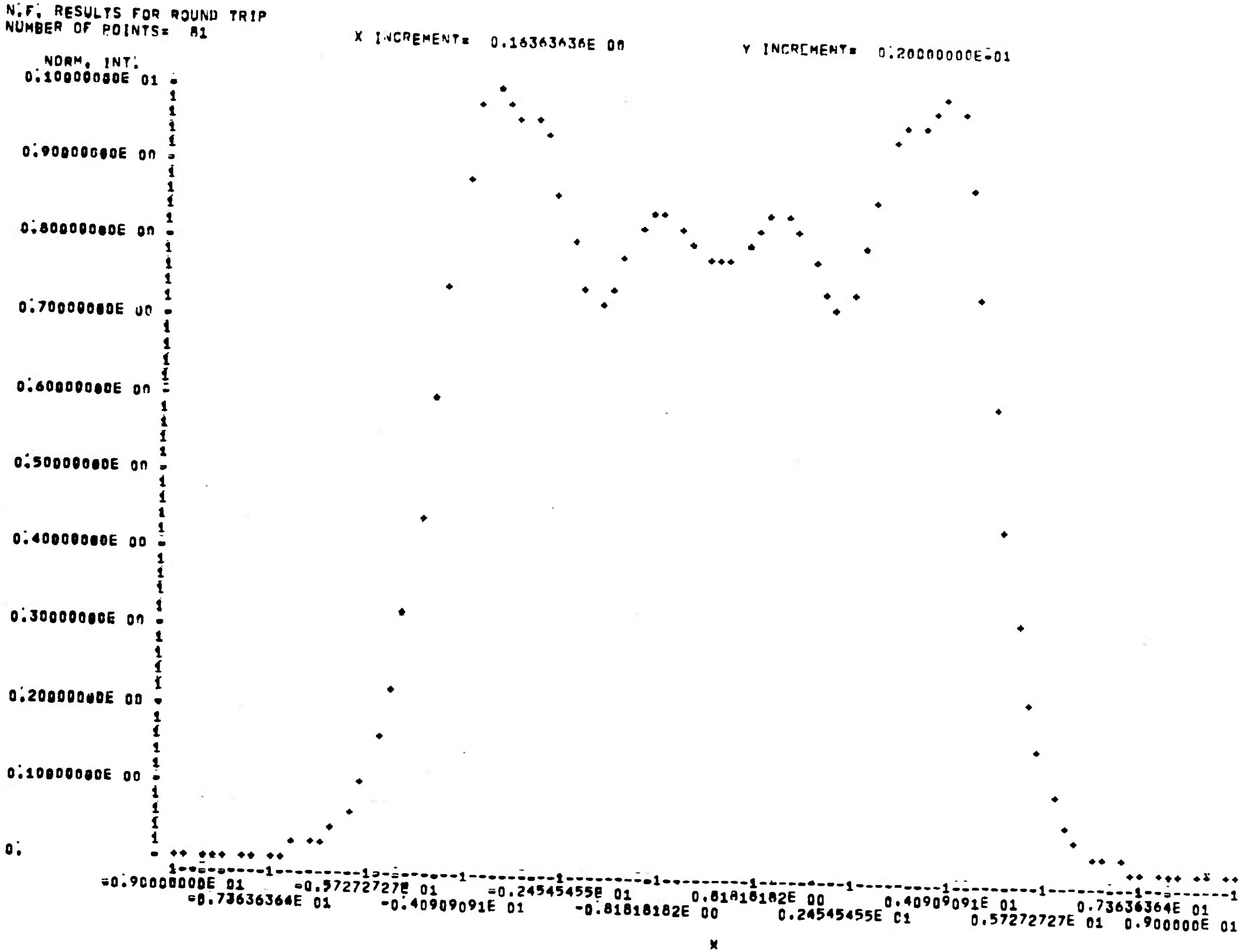
Y INCREMENT= 0.34773900E 00



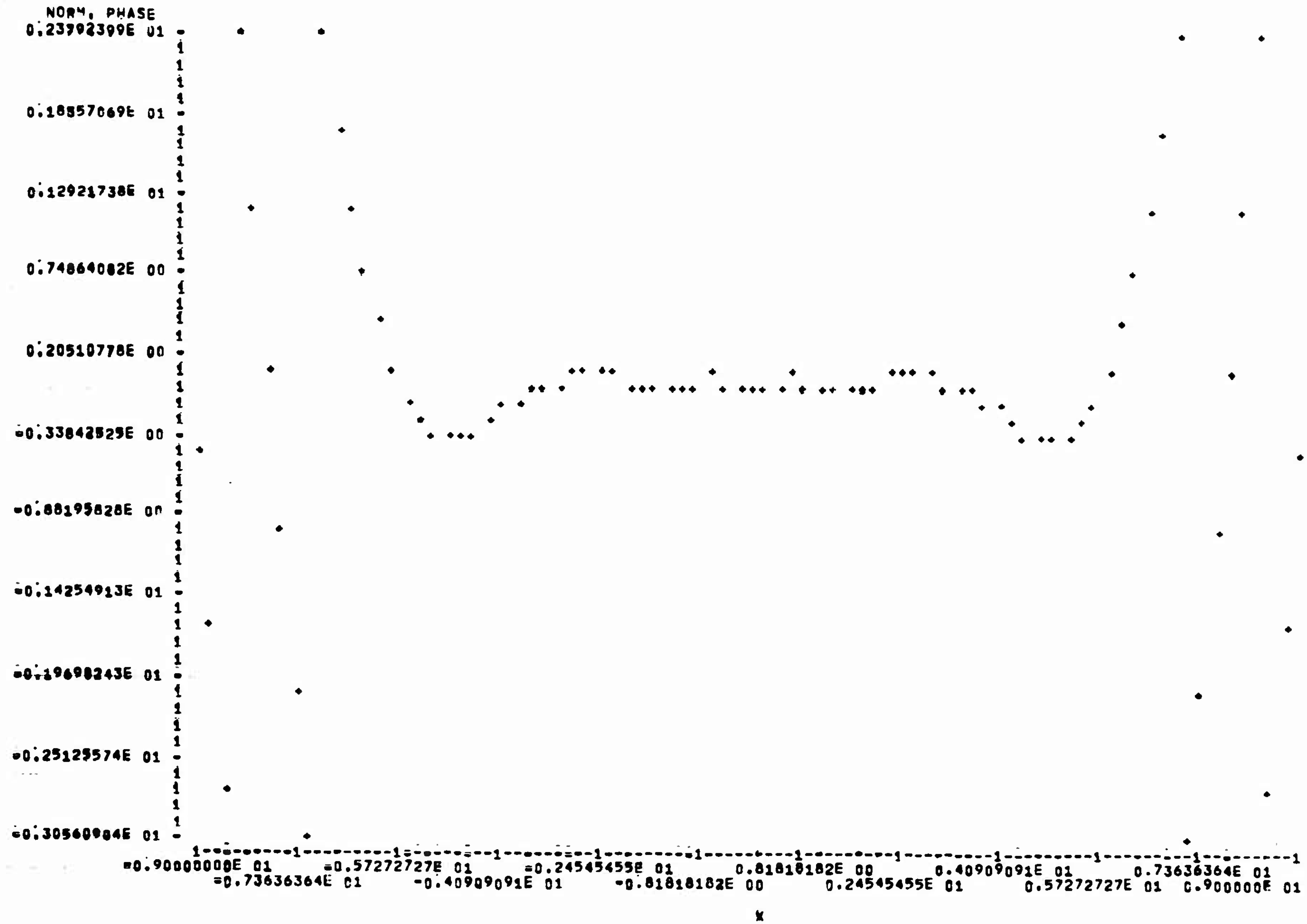
N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 81

X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.20000000E-01

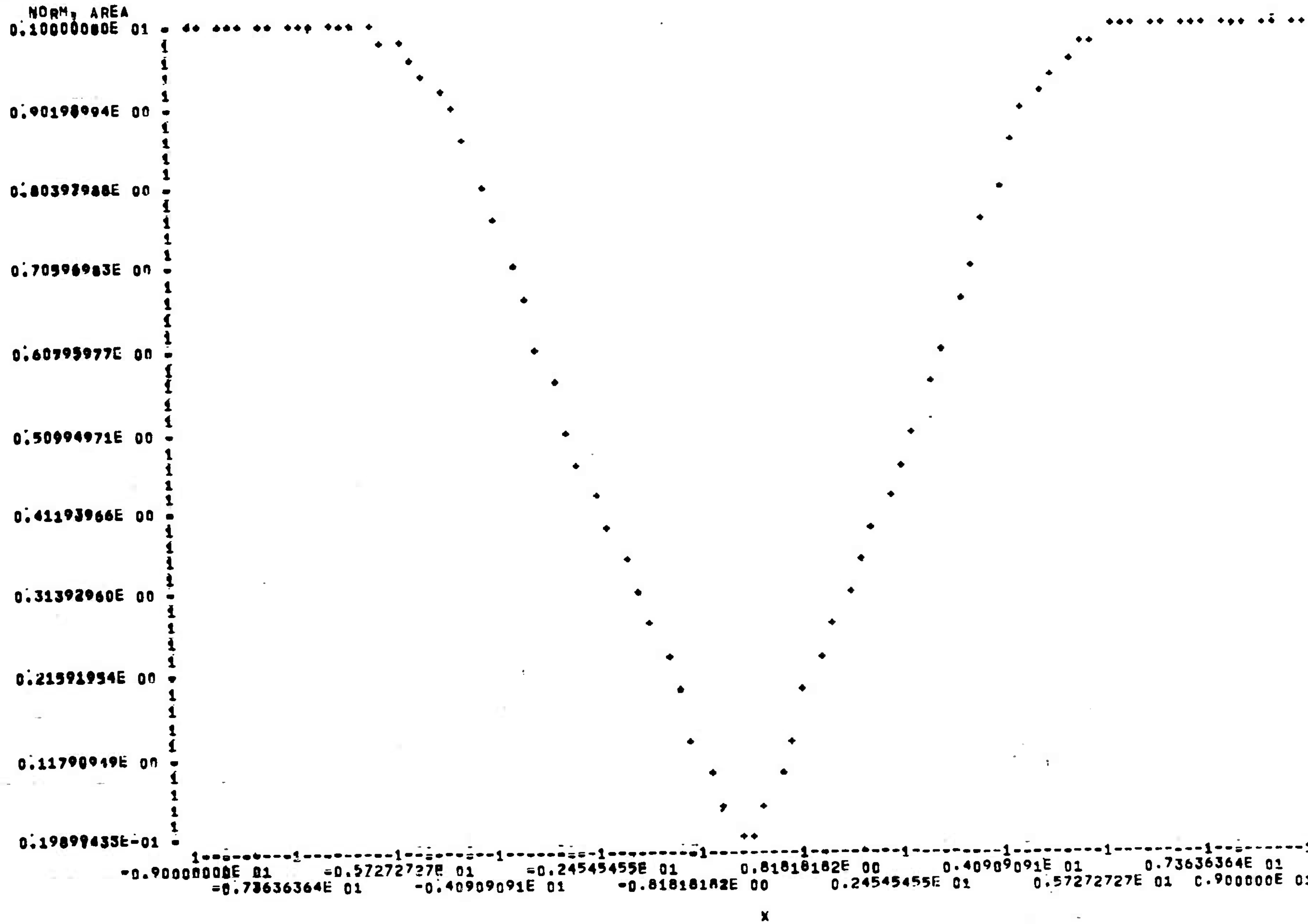



N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 81
X INCREMENT= 0.16363636E 00
Y INCREMENT= 0.20000000E-01
NORM. INT.
0.10000000E 01
0.90000000E 00
0.80000000E 00
0.70000000E 00
0.60000000E 00
0.50000000E 00
0.40000000E 00
0.30000000E 00
0.20000000E 00
0.10000000E 00
0.
-0.90000000E 01
-0.73636364E 01
-0.57272727E 01
-0.40909091E 01
-0.24545455E 01
-0.81818182E 00
0.81818182E 00
0.24545455E 01
0.40909091E 01
0.57272727E 01
0.73636364E 01
0.900000E 01
X

N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 81 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.10870661E 00



N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 81 X INCREMENT= 0.16363636E 00 Y INCREMENT= 0.19602011E-01



```
STARTING PASS NUMBER    2 FOR CASE   8,45

AREA(S) AT START OF PASS
    2D AREA        0.1516770E 03

AFTER INTERPOLATION
    2D AREA        0.1344971E 03

AFTER OUTPUT MIRROR
    2D AREA        0.7974579E 02

AFTER STEP-BY-STEP PROPAGATION
    2D AREA        0.7971669E 02

AFTER MEDIUM
    2D AREA        0.3209774E 03

AFTER STEP-BY-STEP PROPAGATION
    2D AREA        0.3209204E 03

AFTER BACK MIRROR
    2D AREA        0.2973094E 03

AFTER STEP-BY-STEP PROPAGATION
    2D AREA        0.2973098E 03

AFTER MEDIUM
    2D AREA        0.8705350E 03

AFTER STEP-BY-STEP PROPAGATION
    2D AREA        0.8705364E 03

FINISHED PASS NUMBER    2

POWER
    NEAR FIELD POWER=        0.8705364E 03
    OUTPUT POWER AFTER MIRROR=        0.3968980E 03
    POWER DIFFERENCE=        0.4736384E 03
```

APPENDIX E

LISTINGS AND FLOWCHARTS SSCP(ECS)

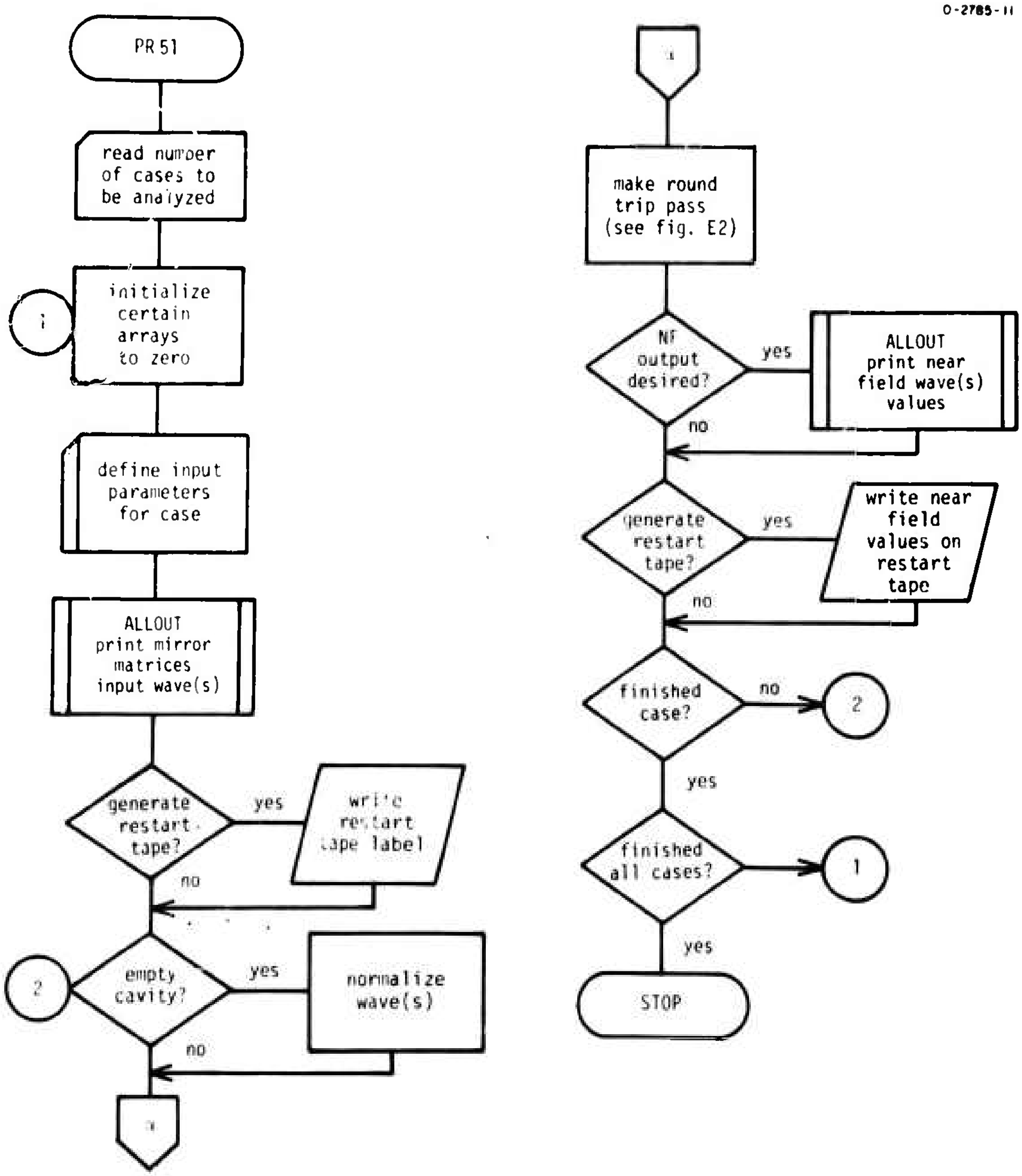


Fig. E1. PR51 logic flow diagram.

0-2785-12

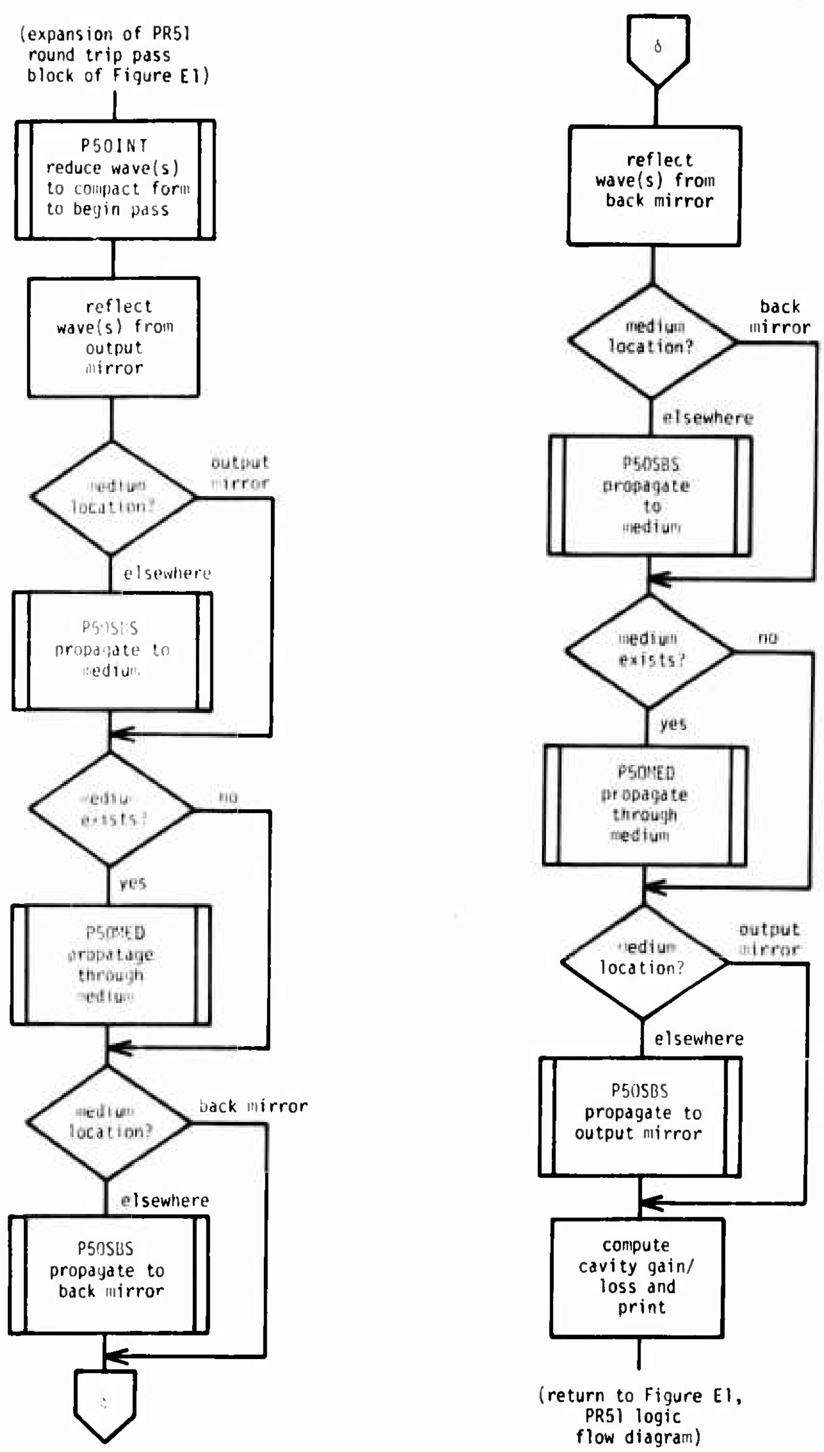


Fig. E2. Logic flow diagram for round trip section of PR51.

```
      PROGRAM PR51(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
     + TAPE12)
*PR51     PR51--EXPANDING COORDINATE SYSTEM STEP-BY-STEP PROP.          1120
C                                                                       1140
      EXTERNAL GAINA                                                    1160
C                                                                       1180
      COMPLEX T(101,2),U(101,2),V(101,2),XMIR1(101),XMIR2(101)          1200
      COMPLEX GAIN(1001,2)                                              1220
C                                                                       1240
      DIMENSION SO(101,21,2),SONEW(101,2),SOTOT(1001,2)                 1260
      DIMENSION XLAMDA(2),XKZERO(2),AMPINT(2),WOMEGA(2)                 1280
      DIMENSION INFOUT(101),DXOLD(21)                                   1300
C                                                                       1320
      COMMON/RCUM/RCUM3D(2)                                             1340
      COMMON /XARRAY/X(101)                                             1360
      COMMON /OT1/OUT1(101)/OT2/OUT2(101)/OT3/OUT3(101)                 1380
      COMMON /OT4/OUT4(101)/OT5/OUT5(101)/OT6/OUT6(101)                 1400
      COMMON /OT7/OUT7(101)                                             1420
      COMMON /CGAINA/ GZERO,XIZERO,TEMP(2)                              1440
C                                                                       1460
      NAMELIST /CASENO/NCASES                                           1480
      NAMELIST/INPUT/CASE,NPASS,IFILE,IRCODE,IROUT,IRTAG,NX,XWIDTH,     1500
     +  NZ,ZLEN,XCENTR,ASR,ZMOLOC,ZLENMD,IGSKIP,GZERO,XIZERO,           1520
     +  NWAVES,XLAMDA,AMPINT,WOMEGA,DIA1,DIA2,REFL1,REFL2,              1540
     +  RCURV1,RCURV2,OMEGA1,OMEGA2,TILT1,TILT2,TLOSS1,INFOUT           1560
      NAMELIST/RUNOPT/NPASS,IFILE,IRCODE,IROUT,IRTAG                    1580
      NAMELIST/CAVITY/NX,XWIDTH,NZ,ZLEN,RCURV1,RCURV2,                  1600
     +  XCENTR,ASR,DXMIR1,DXMIR2,DXOUT,VR1,VR2,G1,G2,ISHIFT,NG          1620
      NAMELIST/MEDIUM/ZMOLOC,ZLENMD,IGSKIP,                             1640
     +  NZMED,NZDIV,NZSTPD,ZLEN1,ZLEN2                                  1660
      NAMELIST /GAINC/GZERO,XIZERO                                      1680
      NAMELIST/WAVES/NWAVES,XLAMDA,AMPINT,WOMEGA,XKZERO,STAB            1700
      NAMELIST/MIRRRS/DIA1,DIA2,REFL1,REFL2,                            1720
     +  OMEGA1,OMEGA2,TILT1,TILT2,TLOSS1,NXC1,NXC2,NXCOUT               1740
      NAMELIST /NRFLD/INFOUT                                            1760
C                                                                       1780
      DATA PI/3.14159265/,PROG/4HPR51/                                  1800
      DATA NXDIM,NZDIM,NWDIM,NPDIM,NGDIM/101,21,2,101,1001/             1820
C                                                                       1840
      DATA TIME,DATE/1H ,1H /
      DATA SNMB/1H /
C                                                                       1900
C           READ NUMBER OF CASES TO BE ANALYZED AND                     1920
C           INITIALIZE MATRICES BEFORE EACH CASE                        1940
C                                                                       1960
      READ(5,CASENO)                                                    1980
      DO 999 ICASE=1,NCASES                                             2000
      DO 30 K=1,NWDIM                                                   2020
      DO 30 I=1,NXDIM                                                   2040
      DO 30 J=1,NZDIM                                                   2060
   30 SO(I,J,K)=0.                                                      2080
      DO 40 I=1,NPDIM                                                   2100
   40 INFOUT(I)=0                                                       2120
C                                                                       2140
C             DEFINE INPUT PARAMETERS                                   2160
C                                                                       2180
C---------------READ TITLE AND RUN CONTROL OPTIONS---------------       2200
```

```
      READ(5,INPUT)
      WRITE(IFILE,9005) PROG,CASE
      WRITE(IFILE,RUNOPT)
C-----------DEFINE CAVITY---------------
      G1=1./(1.-ZLEN/RCURV1)
      G2=1./(1.-ZLEN/RCURV2)
      DENOM=2.-G1-G2
      VR1=ABS(RCURV1/2.)
      VR2=1.E30
      IF(ABS(DENOM).LE. 1.E-3) GO TO 70
      XNUM=SQRT(1.-G1*G2)-1.
      VR1=(XNUM+G2)/DENCM
      VR2=(XNUM+G1)/DENCM
   70 CONTINUE
      DXMIR1=XWIDTH/FLOAT(NX-1)
      DXMIR2=DXMIR1*(1.+ZLEN/VR1)
      DXOUT=DXMIR2*(1.+ZLEN/VR2)
      ISHIFT=(DXOUT-DXMIR1)*FLOAT((NX-1)/2)
      NG=NX+ISHIFT
      IF(NGDIM.GE.NG) GC TO 75
      WRITE(IFILE,9070) CASE,NG
      GO TO 999
   75 DZ=ZLEN/FLOAT(NZ-1)
      ICENT=(NX+1)/2
      DO 80 I=1,NX
   80 X(I)=XCENTR+FLOAT(I-ICENT)*DXOUT
      WRITE(IFILE,CAVITY)
C---------DEFINE MEDIUM------------
      NZMED=ZLENMD/DZ+.999
      NZSTPD=FLOAT(NZMED+1)/FLOAT(NZDIM)+.999
      IF(NZMED.NE.0) NZCIV=FLOAT(NZMED)/FLOAT(NZSTPD)+.999
      ZLEN1=AINT((ZMDLCC-ZLENMD/2.)/DZ)*DZ
      ZLEN2=ZLEN-ZLENMD-ZLEN1
      IZD=NZDIV+1
      DO 90 I=1,IZD
      J=IZD+1-I
      ZCUR=ZLEN-ZLEN2+FLOAT(I-1)*DZ
   90 DXOLD(J)=DXMIR2*(1.+ZCUR/VR2)
      DXMID1=DXMIR1*(1.+ZLEN1/VR1)
      DXMID2=DXMIR1*(1.+(ZLEN1+ZLENMD)/VR1)
      DXMID3=DXMIR2*(1.+ZLEN2/VR2)
      DXMID4=DXMIR2*(1.+(ZLEN2+ZLENMD)/VR2)
      WRITE(IFILE,MEDIUM)
C-----------DEFINE GAIN CONSTANTS---------------------
      WRITE(IFILE,GAINC)
C----------DEFINE WAVE(S)--------------
      XKMAX=-1.E30
      ICENT=(NX+1)/2
      XZERO=X(ICENT)
      DO 110 IWAVE=1,NWAVES
      XKZERO(IWAVE)=2.*PI/XLAMDA(IWAVE)
      XKMAX=AMAX1(XKMAX,XKZERO(IWAVE))
      DO 100 I=1,NX
      IF(WOMEGA(IWAVE).EQ.0.) U(I,IWAVE)=AMPINT(IWAVE)
      IF(WOMEGA(IWAVE).NE.0.) U(I,IWAVE)=
     +   AMPINT(IWAVE)*EXP(-((X(I)-XZERO)/WOMEGA(IWAVE))**2)
  100 CONTINUE
```

```
      U(1,IWAVE)=0.
      U(NX,IWAVE)=0.
  110 CONTINUE
      STAB=.5*XKMAX*DXMIR1*DXMIR1
      IF(DZ.GT.STAB) WRITE(IFILE,9007) DZ,STAB
      IF(IRCODE.GT.0) CALL RSTART(IFILE,IRCODE,IRTAG,NWAVES,NXDIM,
     +   NZDIM,U,SO)
      WRITE(IFILE,WAVES)
      IF(IRCODE.GT.0) REWIND IRCODE
C---------DEFINE MIRRORS-----------
      NXC1=(DIA1-1.17737*OMEGA1)/DXMIR1+.5
      NXCOUT=(DIA1-1.17737*OMEGA1)/DXOUT+.5
      IF(MOD(NXC1,2).NE.0) NXC1=NXC1-1
      NXC2=(DIA2-1.17737*OMEGA2)/DXMIR2+.5
      IF(MOD(NXC2,2).NE.0) NXC2=NXC2-1
      CALL SETMIR(NX,NXC1,DXMIR1,XKZERO,REFL1,1.E30,OMEGA1,TILT1,XMIR1)
      CALL SETMIR(NX,NXC2,DXMIR2,XKZERO,REFL2,1.E30,OMEGA2,TILT2,XMIR2)
      WRITE(IFILE,MIRRRS)
C----------DEFINE NEAR FIELD PRINT OPTIONS-----------
      WRITE(IFILE,9008) (I,I=1,NPASS)
      WRITE(IFILE,9009) (INFOUT(I),I=1,NPASS)
C
C                 WRITE INPUT MATRICES
C
C-----------MIRRORS-------------
      DO 130 I=1,NX
      OUT1(I)=XCENTR+FLOAT(I-ICENT)*DXMIR1
  130 OUT6(I)=XCENTR+FLOAT(I-ICENT)*DXMIR2
      CALL ALLOUT(IFILE,NX,1,6,19,19HMIRROR DESCRIPTIONS,
     +  1,10,10,10HMIRRCR 1 X,OUT1,OUT1,
     +  2,114,12,12HMIRROR 1 INT,XMIR1,OUT2,
     +   2,115,14,14HMIRROR 1 PHASE,XMIR1,OUT3,
     +   1,10,10,10HMIRROR 2 X,OUT6,OUT6,
     +   2,14,12,12HMIRROR 2 INT,XMIR2,OUT4,
     +   2,15,14,14HMIRROR 2 PHASE,XMIR2,OUT5)
      CALL ALLOUT(IFILE,NX,1,3,19,19HMIRROR DESCRIPTIONS,
     +   1,0,10,10HMIRROR 2 X,OUT6,OUT6,
     +   1,100,12,12HMIRROR 2 INT,OUT4,OUT4,
     +   1,100,14,14HMIRROR 2 PHASE,OUT5,OUT5)
C-----------------INPUT WAVE(S)------------------
      DO 140 IWAVE=1,NWAVES
      CALL ALLOUT(IFILE,NX,1,5,22,22HINPUT WAVE DESCRIPTION,
     +   1,10,1,1HX,X,OUT1,
     +   2,113,9,9HMAGNITUDE,U(1,IWAVE),OUT2,
     +   2,114,9,9HINTENSITY,U(1,IWAVE),OUT4,
     +   2,116,10,10HPHASE (DG),U(1,IWAVE),OUT5,
     +   2,1000114,9,9HNORM AREA,U(1,IWAVE),OUT3)
      CALL PWROUT(IFILE,NX,NXC1,ASR,DXOUT,OMEGA1,TLOSS1,REFL1,
     +   U(1,IWAVE),PWRNF,FWROT)
  140 CONTINUE
C
C            GENERATE RESTART TAPE LABEL
C
      IF(IROUT.LE.0) GO TO 200
      WRITE(IROUT) TIME,DATE,SNMB,PROG,CASE
      NZGAIN=1
      IF(NZMED.GT.0) NZGAIN=FLOAT(NZMED)/FLOAT(NZSTPD)+1.9999
```

```
      WRITE(IROUT)NX,NZGAIN,NWAVES,(I,I=1,7),(X(1),I=1,10)
      IPASS=0
      WRITE(IROUT) IPASS
      WRITE(IROUT) ((U(I,J),I=1,NX),J=1,NWAVES)
      WRITE(IROUT) (((SC(I,J,K),I=1,NX),J=1,NZGAIN),K=1,NWAVES)
  200 CONTINUE
C
C           BEGIN MAIN PROPAGATION LOOP
C
      DO 900 IPASS=1,NPASS
      WRITE(IFILE,9010) IPASS,CASE
C----------NORMALIZE PROPAGATION MATRIX, IF NECESSARY-----------
      IF((ZLENMD.EQ.0.) .AND. (ASR.EQ.0.))
     + CALL NORM2D(IFILE,NX,NXDIM,NWAVES,DXOUT,U)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 24,24HAREA(S) AT START OF PASS,DXOUT,U,ASR,AREA2D,AREA3D)
      DO 400 I=1,NWAVES
  400 RCUM3D(I)=1.
C----------MAKE ROUND TRIP PASS-------------
      CALL P50INT(NX,NXDIM,NWAVES,DXMIR1,DXOUT,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +  19,19HAFTER INTERPOLATION,DXMIR1,U,ASR,AREA2D,AREA3D)
      CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR1)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 19,19HAFTER OUTPUT MIRROR,DXMIR1,U,ASR,AREA2D,AREA3D)
      CALL P50SBS(NWAVES,NX,NXDIM,XKZERO,ASR,DXMIR1,VR1,DZ,
     +   0.,ZLEN1,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DXMID1,U,ASR,AREA2D,AREA3D)
      CALL P50MED(NX,NXDIM,NWAVES,NZDIM,NGDIM,IGSKIP,NZDIV,NZSTPD,+1,
     +   ZLEN1,ZLEN1+ZLENMD,ASR,DXMIR1,ZLEN,VR1,VR2,DIA2,
     +   XKZERO,DXOLD,SCNEW,SOTOT,SO,T,U,V,GAIN,GAINA)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +   12,12HAFTER MEDIUM,DXMID2,U,ASR,AREA2D,AREA3D)
      CALL P50SBS(NWAVES,NX,NXDIM,XKZERO,ASR,DXMIR1,VR1,DZ,
     +   ZLEN1+ZLENMD,ZLEN,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DXMIR2,U,ASR,AREA2D,AREA3D)
      IF(ASR.GT.0.) WRITE(IFILE,9090) (RCUM3D(I),I=1,NWAVES)
      DO 500 I=1,NWAVES
  500 RCUM3D(I)=1.
      CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR2)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +   17,17HAFTER BACK MIRROR,DXMIR2,U,ASR,AREA2D,AREA3D)
      CALL P50SBS(NWAVES,NX,NXDIM,XKZERO,ASR,DXMIR2,VR2,DZ,
     +   0.,ZLEN2,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DXMID3,U,ASR,AREA2D,AREA3D)
      CALL P50MED(NX,NXDIM,NWAVES,NZDIM,NGDIM,IGSKIP,NZDIV,NZSTPD,-1,
     +   ZLEN1+ZLENMD,ZLEN1,ASR,DXMIR1,ZLEN,VR1,VR2,DIA2,XKZERO,
     +   DXOLD,SONEW,SOTOT,SO,T,U,V,GAIN,GAINA)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     +   12,12HAFTER MEDIUM,DXMID4,U,ASR,AREA2D,AREA3D)
      CALL P50SBS(NWAVES,NX,NXDIM,XKZERO,ASR,DXMIR2,VR2,DZ,
     +   ZLEN2+ZLENMD,ZLEN,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
     + 30,30HAFTER STEP-BY-STEP PROPAGATION,DXOUT,U,ASR,AREA2D,AREA3D)
```

```
      IF(ASR.GT.0.) WRITE(IFILE,9090) (RCUM3D(I),I=1,NWAVES)
C-------------OUTPUT FOR ROUND TRIP PASS--------------
      WRITE(IFILE,9060) IPASS
      DO 600 IWAVE=1,NWAVES
      CALL PWROUT(IFILE,NX,NXCOUT,ASR,DXOUT,OMEGA1,TLOSS1,REFL1,
     +   U(1,IWAVE),PWRNF,PWROT)
      IF(INFOUT(IPASS).GE.1)
     +    CALL ALLOUT(IFILE,NX,1,7,27,27HN.F. RESULTS FOR ROUND TRIP,
     +  1,10,1,1HX,X,OUT1,
     +  2,113,9,9HMAGNITUDE,U(1,IWAVE),OUT2,
     +  2,114,9,9HINTENSITY,U(1,IWAVE),OUT3,
     +  2,220113,10,10HNORM. MAG.,U(1,IWAVE),OUT4,
     +   2,220114,10,10HNORM. INT.,U(1,IWAVE),OUT5,
     +  2,110115,11,11HNORM. PHASE,U(1,IWAVE),OUT6,
     +  2,1000114,10,10HNORM. AREA,U(1,IWAVE),OUT7)
  600 CONTINUE
C----------WRITE INFORMATION ON RESTART TAPE-----------
      IF(IROUT.GT.0) WRITE(IROUT) IPASS
      IF(IROUT.GT.0) WRITE(IROUT) ((U(I,J),I=1,NX),J=1,NWAVES)
      IF(IROUT.GT.0) WRITE(IROUT) (((SO(I,J,K),I=1,NX),
     +    J=1,NZGAIN),K=1,NWAVES)
C-------------TERMINATION OF PROPAGATION LOOP-------------
  900 CONTINUE
C
C         PROGRAM TERMINATION
C
      IF(IROUT.GT.0) ENDFILE IROUT
  999 CONTINUE
      STOP
C
C              FORMATS
C
 9005 FORMAT(1H1,7HPROGRAM, 5X, A6/1X,4HCASE,8X,F6.2)
 9007 FORMAT(1H1,25(/130(1H*))/30X,7HDELTA Z, E20.7,
     +    2X,31HGREATER THAN STABILITY CRITERIA,E20.7,25(/130(1H*)))
 9008 FORMAT(1H0,11HPASS NUMBER/(1X,40I3))
 9009 FORMAT(1X,17HNF OUTPUT OPTIONS/(1X,40I3))
 9010 FORMAT(1H1,20HSTARTING PASS NUMBER,I5,10H FOR CASE ,F6.2)
 9060 FORMAT(1H0,20HFINISHED PASS NUMBER,I5)
 9070 FORMAT(1H1,5HCASE ,F8.2,26HABORTED--INCREASE NGDIM TO,I10)
 9090 FORMAT(1H0,5X,17HCUMULATIVE RATIOS/(5X,E15.7))
      END
```

```
      SUBROUTINE P50GAI(NX,NXDIM,NWAVES,NZDIM,NGDIM,L,L2,             7300
     +   ASR,DXMIN,ZLEN,VR1,VR2,ZCUR,DXCUR,R1,DIA2,                   7320
     +   U,SOTOT,SO,DXOLD,GAIN,GAINS)                                 7340
      COMPLEX U(NXDIM,NWAVES),GAIN(NGDIM,NWAVES)                      7360
      DIMENSION SOTOT(NGDIM,NWAVES),SO(NXDIM,NZDIM,NWAVES),           7380
     +   DXOLD(NZDIM)                                                 7400
       COMMON/CGAINA/TEMP(2),XSTART,TEMP3                             7420
C                                                                     6540
C---------------------------------------------------------------      6560
C P50GAI ROUTINE COMPUTES SUM OF OLD AND NEW INTENSITIES BY LINEAR    6580
C        INTERPOLATION CF SO MATRIX, THEN CALLS GAIN ROUTINE FOR      6600
C        RETURN OF GAIN VALUES                                        6620
C----------------------------------------------------------------     6640
C   THE PARAMETERS ARE                                                6660
C                                                                     6680
C NX     THE NUMBER OF FROPAGATING MESH POINTS                        6700
C NXDIM  THE X-DIMENSION OF THE PROPAGATING MATRIX                    6720
C NWAVES THE NUMBER OF FROPAGATING WAVES                              6740
C NZDIM  THE Z-DIMENSION OF THE SO MATRIX                             6760
C NGDIM  THE DIMENSION ALONG X OF SOTOT AND GAIN ARRAYS               6780
C L      THE Z-INDEX OF THE LAST LINE STORED IN SO                    6800
C L2     THE Z-INDEX OF THE NEXT LINE TO BE STORED IN SO              6820
C ASR    3D AREA SWITCH                                               6840
C DXMIN  THE SMALLER DELTA-X AT THE OUTPUT MIRROR                     6860
C ZLEN   THE DISTANCE BETWEEN MIRRORS                                 6880
C VR1    THE VIRTUAL RADIUS OF CURV. FOR THE OUTPUT MIRROR            6900
C VR2    THE VIRTUAL RADIUS OF CURV. FOR THE BACK MIRROR              6920
C ZCUR   THE CURRENT DISTANCE FROM THE OUTPUT MIRROR                  6940
C DXCUR  THE CURRENT VALUE OF DELTA-X                                 6960
C R1     PERCENT OF Z-INTERVAL TRAVERSED BETWEEN SO STORES            6980
C DIA2   DIAMETER OF BACK MIRROR                                      7000
C U      PROPAGATING MATRIX                                           7020
C SOTOT  DUMMY MATRIX                                                 7040
C SO     PAST INTENSITIES MATRIX                                      7060
C DXOLD  VECTOR STORING LAST PASS DX FOR EACH STORED SO LINE          7080
C GAIN   MATRIX OF COMPUTED GAIN VALUES (RETURNED)                    7100
C GAINS  NAME OF GAIN RCUTINE (TYPED EXTERNAL ELSEWHERE)              7120
C                                                                     7140
C   SUBPROGRAMS REQUIRED--                                            7160
C      GAINS (TO RETURN A SET OF GAIN VALUES FOR CURRENT Z)           7180
C      P5GGET (TO FETCH A LAST-PASS INTENSITY VALUE FROM SO)          7200
C                                                                     7220
C   8/28/73   CREATED (NEW ROUTINE)                                   7240
C-----------------------------------------------------------------    7260
C                                                                     7280
C                                                                     7440
C          ESTABLISH SHIFT PARAMETER, IF NEEDED                       7460
C                                                                     7480
      ISHIFT=0                                                        7500
      IF(L2.LT.L) GO TO 300                                           7520
      XSTART=DXMIN*(1.+ZLEN/VR1)*(1.+(ZLEN-ZCUR)/VR2)*                7540
     +   FLOAT((NX-1)/2)                                              7560
      XSTCUR=DXCUR*FLOAT((NX-1)/2)                                    7580
      ISHIFT=MAX1((XSTART-XSTCUR)/DXCUR,0.)                           7600
      IF(ISHIFT.EQ.0) GC TO 300                                       7620
C                                                                     7640
C       WHEN HEADING TOWARD BACK MIRROR, COMPUTE LAST-PASS            7660
```

```
C      INTENSITIES FOR REGION PRECEEDING CURRENT MATRIX
C
      DO 200 JWAVE=1,NWAVES
      DO 200 I=1,ISHIFT
      IX=I-ISHIFT
      CALL P50GET(IX,NX,NXDIM,L,L2,R1,DXCUR,SO(1,1,JWAVE),DXOLD,XINT)
  200 SOTOT(I,JWAVE)=XINT
C
C      FILL REMAINING (NX) LOCATIONS OF SOTOT WITH SUM OF
C      INTERPOLATED OLD INTENSITIES AND COMPUTED NEW INTENSITIES
C
  300 DO 500 JWAVE=1,NWAVES
      DO 500 IX=1,NX
      I=IX+ISHIFT
      CALL P50GET(IX,NX,NXDIM,L,L2,R1,DXCUR,SO(1,1,JWAVE),DXOLD,XINT)
  500 SOTOT(I,JWAVE)=XINT+REAL(U(IX,JWAVE))**2+AIMAG(U(IX,JWAVE))**2
C
C        ADJUST SOTOT ARRAY IF ASR .GT. 0.
C
      IF(ASR.LE.0.) GO TO 600
      IX=NX+ISHIFT
      ICENT =(NX+1)/2+ISHIFT
      DO 550 I=1,IX
      SOASR=ASR*ABS(FLOAT(I-ICENT))*DXCUR/DIA2
      DO 550 JWAVE=1,NWAVES
  550 SOTOT(I,JWAVE)=SOASR*SOTOT(I,JWAVE)
C
C          COMPUTE GAIN FOR EACH WAVE
C
  600 CALL GAINS(NX+ISHIFT,NGDIM,NWAVES,SOTOT,GAIN)
C
C            SHIFT GAIN MATRIX BACK TO NORMAL FORM
C
      DO 700 JWAVE=1,NWAVES
      DO 700 I=1,NX
      IX=I+ISHIFT
  700 GAIN(I,JWAVE)=GAIN(IX,JWAVE)
      RETURN
      END
```

```
      SUBROUTINE P50GET(IX,NX,NXDIM,L,L2,R1,DXCUR,SO,DXOLD,XINT)          8960
      DIMENSION SO(NXDIM,1),DXOLD(1)                                      8980
C---ASF TO YIELD EQUIVALENT X-INDEX FOR OTHER Z-POSITION                  9000
      EQUIVI(I,DXLAST)=FLOAT(ICENT)-FLOAT(ICENT-I)*DXCUR/DXLAST           9020
C---ASF TO RETURN INTERFOLATED VALUE GIVEN POSITION RATIO                  9040
      XINTRP(R,X1,X2)=X1+R*(X2-X1)                                        9060
C                                                                          8500
C-------------------------------------------------------------            8520
C P50GET RETRIEVES AN INTENSITY VALUE FROM THE SO MATRIX BY                8540
C      3-WAY LINEAR INTERPOLATION                                          8560
C-------------------------------------------------------------            8580
C   THE PARAMETERS ARE                                                     8600
C                                                                          8620
C IX     THE X-INDEX OF THE DESIRED INTENSITY RELATIVE TO CURRENT U        8640
C NX     THE NUMBER OF PROPAGATING POINTS                                  8660
C NXDIM  THE X-DIMENSION OF THE LAST-PASS MATRIX                           8680
C L      THE Z-INDEX OF THE START OF THE Z-INTERVAL                        8700
C L2     THE Z-INDEX OF THE NEXT Z-STORED LINE (L+1 OR L-1)                8720
C R1     THE RATIO DESCRIBING CURRENT Z-POSITION IN THE INTERVAL           8740
C DXCUR  DELTA-X FOR THE CURRENT Z-POSITION                                8760
C SO     THE LAST-PASS INTENSITY MATRIX                                    8780
C DXOLD  VECTOR SAVING LAST PASS DELTA-X FOR L AND L2 POSITICNS            8800
C XINT   RETURNED VALUE OF INTENSITY RETRIEVED FRCM SO                     8820
C                                                                          8840
C   SUBPROGRAMS REQUIREC--NONE                                             8860
C                                                                          8880
C   8/28/73   CREATED (NEW ROUTINE)                                        8900
C-------------------------------------------------------------            8920
C                                                                          8940
C                                                                          9080
C      COMPUTE INTENSITY FOR LINE L OF SO MATRIX                           9100
C                                                                          9120
      ICENT=(NX+1)/2                                                      9140
      XI=EQUIVI(IX,DXOLD(L))                                              9160
      I=XI                                                                9180
      R2=XI-FLOAT(I)                                                      9200
      XINT1=0.                                                            9220
      IF(I.LE.0) GO TO 100                                                9240
      XINT1=XINTRP(R2,SO(I,L),SO(I+1,L))                                  9260
  100 CONTINUE                                                            9280
C                                                                          9300
C     CHECK FOR TRIVIAL CASE OF R1=0.                                      9320
C                                                                          9340
      IF(R1.LE.C.) XINT=XINT1                                             9360
      IF(R1.LE.0.) GO TC 999                                              9380
C                                                                          9400
C          COMPUTE INTENSITY FOR LINE L2 OF SO MATRIX                      9420
C                                                                          9440
      XI=EQUIVI(IX,DXOLD(L2))                                             9460
      I=XI                                                                9480
      R3=XI-FLCAT(I)                                                      9500
      XINT2=0.                                                            9520
      IF(I.LE.0) GO TO 300                                                9540
      XINT2=XINTRP(R3,SO(I,L2),SO(I+1,L2))                                9560
  300 CONTINUE                                                            9580
C                                                                          9600
C          INTERPOLATE IN Z TO OBTAIN INTENSITY VALUE                      9620
```

```
C                                                        9640
      XINT=XINTRP(R1,XINT1,XINT2)                        9660
C                                                        9680
C             RETURN WITH REQUIRED INTENSITY             9700
C                                                        9720
  999 RETURN                                             9740
      END                                                9760
```

```
      SUBROUTINE P5DINT(NX,NXDIM,NWAVES,DXNEW,DXOLD,U,V)
      COMPLEX U(NXDIM,NWAVES),V(NXDIM,NWAVES)
C
C-------------------------------------------------------------
C P5DINT GIVEN A COMPLEX MATRIX WITH ONE MESH SPACING, INTERPOLATES
C        LINEARLY TO RETURN THE SAME SIZE MATRIX BUT WITH DIFFERENT
C        MESH SPACING
C--------------------------------------------------------------
C   THE PARAMETERS ARE
C
C NX     NUMBER OF PROPAGATING MESH PRINTS
C NXDIM  X-DIMENSION OF PROPAGATING MATRIX
C NWAVES NUMBER OF PROPAGATING WAVES
C DXNEW  MESH SPACING IN X OF MATRIX TO BE RETURNED
C DXOLD  ORIGINAL MESH SPACING
C U      ORIGINAL AND RETURNED PROPAGATING MATRIX
C V      DUMMY MATRIX
C
C   SUBPROGRAMS REQUIRED--NONE
C
C   8/23/73   CREATED (NEW PROGRAM)
C---------------------------------------------------------------
C
      XCENT=(NX+1)/2
      NXP=(NX+1)/2+1
C
C               CREATE INTERPOLATED MATRIX (V) FROM VALUES IN U
C
      DO 100 I=NXP,NX
C---(XJ=EXACT INTERVAL POSITION IN U CORRESPONDING TO I IN V)
C---(J=TRUNCATED VALUE OF XJ)
C---(PRCENT=PERCENT VALUE FOR THE INTERPOLATION OF THE U-INTERVAL)
      XJ=XCENT-(XCENT-FLOAT(I))*DXNEW/DXOLD
      J=XJ
      PRCENT=AMOD(XJ,1.)
C---(IP=VALUE OF I IN FIRST HALF OF V, BY SYMMETRY)
C---(JP=VALUE OF J IN FIRST HALF OF U, BY SYMMETRY)
      IP=(NX+1)-I
      JP=(NX+1)-J
C-----------FOR EACH WAVE, COMPUTE BOTH INTERPOLATED POINTS IN V----
      DO 100 IWAVE=1,NWAVES
      V(I,IWAVE)=(U(J+1,IWAVE)-U(J,IWAVE))*PRCENT+U(J,IWAVE)
      V(IP,IWAVE)=(U(JP-1,IWAVE)-U(JP,IWAVE))*PRCENT+U(JP,IWAVE)
  100 CONTINUE
      DO 200 IWAVE=1,NWAVES
  200 V(NXP-1,IWAVE)=U(NXP-1,IWAVE)
C
C          SHIFT FINAL VALUES BACK INTO U
      DO 500 I=1,NX
      DO 500 IWAVE=1,NWAVES
  500 U(I,IWAVE)=V(I,IWAVE)
      RETURN
      END
```

0-2785-13

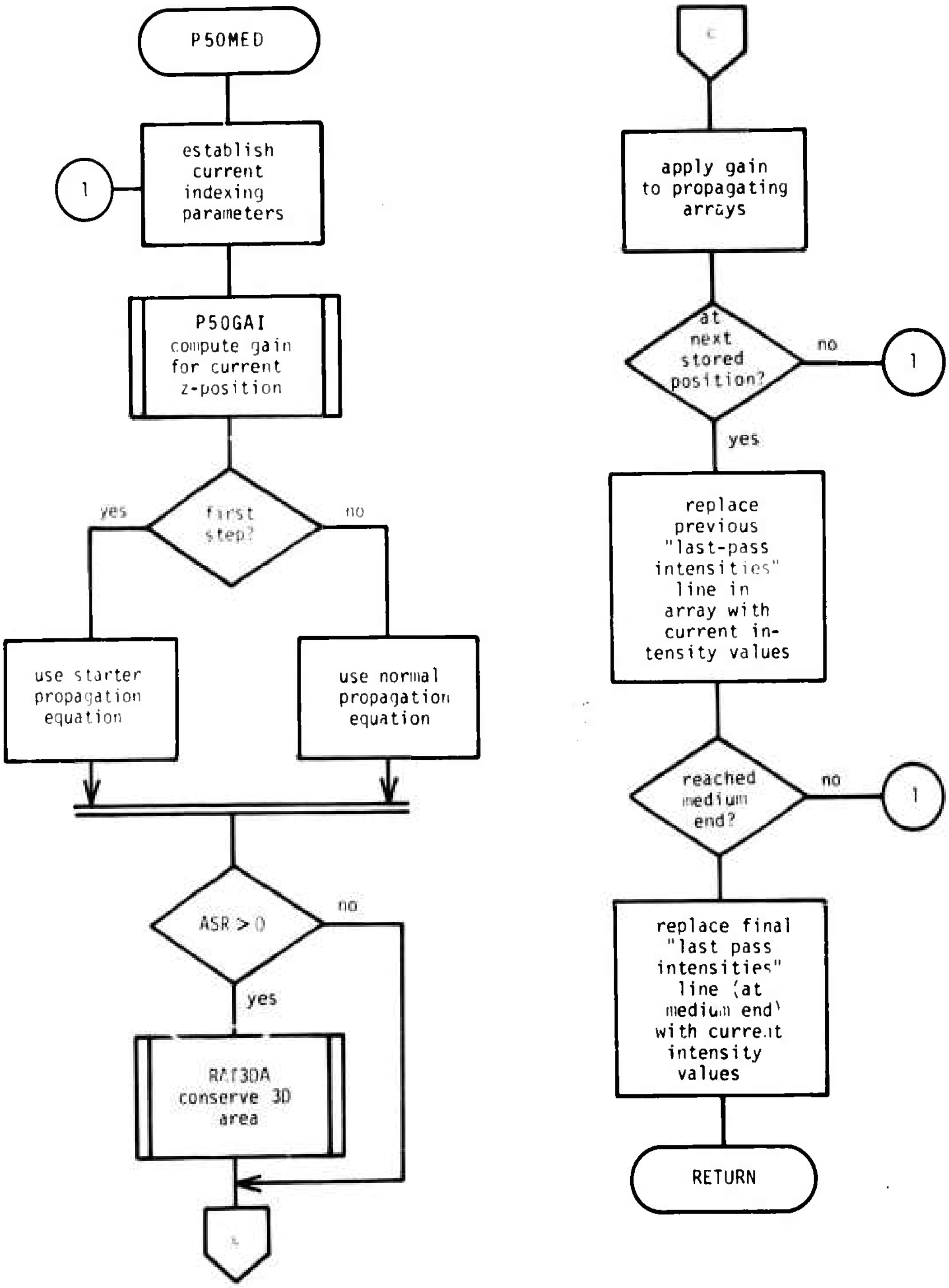


Fig. E3. P50MED logic flow diagram.

```
      SUBROUTINE P50MED(NX,NXDIM,NWAVES,NZDIM,NGDIM,IGSKIP,NZD,               11800
     +   NZSTPD,IDIR,ZSTART,ZFIN,ASR,DXMIN,ZLEN,VR1,VR2,DIA2,                 11820
     +   XK0,DXOLD,SONEW,SOTOT,SO,T,U,V,GAIN,GAINS)                           11840
      COMPLEX T(NXDIM,NWAVES),U(NXDIM,NWAVES),V(NXDIM,NWAVES),                11860
     +   GAIN(NGDIM,NWAVES),GNX                                               11880
      DIMENSION XK0(NWAVES),DXOLD(NZDIM),SONEW(NXDIM,NWAVES),                 11900
     +   SOTOT(NGDIM,NWAVES),SO(NXDIM,NZDIM,NWAVES)                           11920
      COMMON /CGAINA/TEMP(3),DXCUR                                            11940
C                                                                             10920
C------------------------------------------------------------------           10940
C P50MED PROPAGATES (NWAVES) WAVEFORMS THROUGH A MEDIUM                       10960
C-------------------------------------------------------------------          10980
C   THE PARAMETERS ARE                                                        11000
C                                                                             11020
C NX     THE NUMBER OF PROPAGATING MESH POINTS                                11040
C NXDIM  THE X-DIMENSION OF THE PROPAGATING MATRIX                            11060
C NWAVES THE NUMBER OF PROPAGATING WAVES                                      11080
C NZDIM  THE Z-DIMENSION (2ND) OF THE SO MATRIX                               11100
C NGDIM  DIMENSION ALONG X OF SOTOT AND GAIN ARRAYS                           11120
C IGSKIP  SKIP PARAMETER FOR GAIN ROUTINE CALL                                11140
C NZD    NO. OF INTENSITY STORES (MINUS 1) IN SO ALONG Z-DIRECTION            11160
C NZSTPD NO. OF PROP. STEPS TAKEN THRU MEDIUM BETWEEN STORES                  11180
C IDIR   DIRECTION OF PROPAGATION                                             11200
C   .NE. -1   TOWARD BACK MIRROR                                              11220
C   .EQ. -1   TOWARD OUTPUT MIRROR                                            11240
C ZSTART DISTANCE FROM OUTPUT MIRROR TO START OF PROPAGATION                  11260
C ZFIN   DISTANCE FROM OUTPUT MIRROR TO END OF PROPAGATION                    11280
C ASR    3D PROPAGATION SWITCH (IF .GT. 0.)                                   11300
C DXMIN  SMALLER OF THE DELTA-X VALUES AT THE OUTPUT MIRROR                   11320
C ZLEN   DISTANCE BETWEEN MIRRORS                                             11340
C VR1    VIRTUAL RADIUS OF CURVATURE OF OUTPUT MIRROR                         11360
C VR2    VIRTUAL RADIUS OF CURVATURE OF BACK MIRROR                           11380
C DIA2   DIAMETER OF BACK MIRROR                                              11400
C XK0    VECTOR OF K=2*PI/LAMBDA, ONE VALUE FOR EACH WAVE                     11420
C*DXOLD  VECTOR OF LAST PASS DELTA-X VALUES (ONE FOR EACH STORE)              11440
C*SONEW  DUMMY ARRAY                                                          11460
C*SOTOT  DUMMY ARRAY                                                          11480
C*SO     LAST PASS INTENSITY VALUES                                           11500
C*T      DUMMY ARRAY                                                          11520
C*U      PROPAGATING ARRAY                                                    11540
C*V      DUMMY ARRAY                                                          11560
C*GAIN   DUMMY ARRAY                                                          11580
C GAINS  NAME OF GAIN ROUTINE (TYPED EXTERNAL ELSEWHERE)                      11600
C   (* ALTERED DURING COMPUTATION)                                            11620
C                                                                             11640
C   SUBPROGRAMS REQUIRED--                                                    11660
C      P50GAI  (COMPUTES GAIN VALUES AT A Z-LOCATION)                         11680
C      RAT3DA  (CONSERVES 3D AREA, IF ASR .GT. 0)                             11700
C                                                                             11720
C   8/29/73   CREATED FROM OUTLINE OF PRPGAI (PR20 ROUTINE)                   11740
C-----------------------------------------------------------------            11760
C                                                                             11780
C                                                                             11960
C          BEGIN PROPAGATION THROUGH MEDIUM                                   11980
C                                                                             12000
      IGCNT=0                                                                 12020
      NXM1=NX-1                                                               12040
```

```
      IF(ZSTART.EQ.ZFIN) GO TO 999
      DZ=ABS(ZSTART-ZFIN)/FLOAT(NZD*NZSTPD)
C
C   PROPAGATE OVER DISTANCE (ZFIN-ZSTART) USING (NZD*NZSTPD) STEPS
C
      DO 500 IZD=1,NZD
C----COMPUTE CURRENT (L) AND NEXT (L2) STORAGE INDICES FOR SO----
      L=IZD
      IF(IDIR.EQ.(-1)) L=NZD+2-IZD
      L2=L+1
      IF(IDIR.EQ.(-1)) L2=L-1
      DO 300 J=1,NZSTPD
C---COMPUTE CURRENT Z, DX, INTERP. RATIO, AND PROP. CONSTANTS---
      ZCUR=ZSTART+FLOAT((IZD-1)*NZSTPD+J-1)/FLOAT(NZD*NZSTPD)*
     +   (ZFIN-ZSTART)
      IF(IDIR.NE.(-1)) DXCUR=DXMIN*(1.+ZCUR/VR1)
      IF(IDIR.EQ.(-1)) DXCUR=DXMIN*(1.+ZLEN/VR1)*(1.+(ZLEN-ZCUR)/VR2)
      R1=FLOAT(J-1)/FLOAT(NZSTPD)
      IF(IDIR.NE.(-1)) F=ZCUR+VR1
      IF(IDIR.EQ.(-1)) F=(ZLEN-ZCUR)+VR2
      AA=1.-DZ/(2.*F)
      IF(J.NE.1) GO TO 50
C*******SAVE DX AND LINE OF CURRENT INTENSITIES FOR LATER SAVE*******
      DO 40 JWAVE=1,NWAVES
      DO 40 I=1,NX
   40 SONEW(I,JWAVE)=REAL(U(I,JWAVE))**2+AIMAG(U(I,JWAVE))**2
      DXSAVE=DXCUR
C----------COMPUTE GAIN FOR FOLLOWING PROPAGATION STEP------------
   50 IF(MOD(IGCNT,IGSKIP).EQ.0)
     +   CALL P5GGAI(NX,NXDIM,NWAVES,NZDIM,NGDIM,L,L2,ASR,DXMIN,
     +      ZLEN,VR1,VR2,ZCUR,DXCUR,R1,DIA2,U,SOTOT,
     +      SO,DXOLD,GAIN,GAINS)
      IGCNT=IGCNT+1
      IF(.NOT.(IZD.EQ.1 .AND. J.EQ.1)) GO TO 200
C---------(VERY FIRST PROPAGATION STEP ONLY)------------
      DO 150 JWAVE=1,NWAVES
      DELX=DZ/(XK0(JWAVE)*DXCUR*DXCUR)
      V(1,JWAVE)=0.
      V(NX,JWAVE)=0.
      DO 150 IX=1,NX
  150 V(IX,JWAVE)=AA*(U(IX,JWAVE)+.5*DELX*(0.,1.)*
     +   (U(IX+1,JWAVE)-2.*U(IX,JWAVE)+U(IX-1,JWAVE)))
      GO TO 280
C----------(SUCCEEDING PROPAGATION STEPS)------------------
  200 DO 250 JWAVE=1,NWAVES
      DELX=DZ/(XK0(JWAVE)*DXCUR*DXCUR)
      DELXSQ=DELX*DELX
      DO 250 IX=2,NXM1
  250 V(IX,JWAVE)=
     +   AA/(1.+DELXSQ)*
     +      (T(IX,JWAVE)*AA+
     +       (0.,1.)*DELX*(U(IX+1,JWAVE)-2.*T(IX,JWAVE)*AA+
     +         U(IX-1,JWAVE))+
     +      DELXSQ*(U(IX+1,JWAVE)-T(IX,JWAVE)*AA+U(IX-1,JWAVE)))
C-----------AFTER A DZ STEP, CONSERVE 3D AREA (IF ASR .GT. 0)------
  280 IF(ASR.LE.0.) GO TO 285
      IF(IDIR.NE.(-1)) DXNEXT=DXMIN*(1.+(ZCUR+DZ)/VR1)
```

```
      IF(IDIR.EQ.(-1)) CXNEXT=
     +    DXMIN*(1.+ZLEN/VR1)*(1.+(ZLEN-ZCUR-DZ)/VR2)
      CALL RAT3DA(NX,NXCIM,NWAVES,DXNEXT,DXCUR,V,U)
  285 CONTINUE
C-----------MOVE ARRAYS DOWN AND APPLY GAIN------------------
      DO 290 JWAVE=1,NWAVES
      DO 290 I=2,NXM1
      GNX=CEXP(DZ*CMPLX(.5*REAL(GAIN(I,JWAVE)),AIMAG(GAIN(I,JWAVE))))
      T(I,JWAVE)=U(I,JWAVE)*GNX
  290 U(I,JWAVE)=V(I,JWAVE)*GNX
  300 CONTINUE
C-------------------LOAD NEW LINE INTO PAST INTENSITIES MATRIX---------
      DO 400 JWAVE=1,NWAVES
      DO 400 I=1,NX
  400 SO(I,L,JWAVE)=SONEW(I,JWAVE)
      DXOLD(L)=DXSAVE
  500 CONTINUE
C
C          ADJUST V, SC, AND  DXOLD MATRICES AT Z=ZFIN
C
      DO 600 JWAVE=1,NWAVES
      DO 600 I=1,NX
      V(I,JWAVE)=U(I,JWAVE)
  600 SO(I,L2,JWAVE)=REAL(U(I,JWAVE))**2+AIMAG(U(I,JWAVE))**2
      IF(IDIR.NE.(-1))  CXCUR=DXMIN*(1.+ZFIN/VR1)
      IF(IDIR.EQ.(-1))  CXCUR=DXMIN*(1.+ZLEN/VR1)*(1.+(ZLEN-ZFIN)/VR2)
      DXOLD(L2)=DXCUR
C
C        PROPAGATION TO Z=ZFIN COMPLETE
C
  999 RETURN
      END
```

0-2785-14

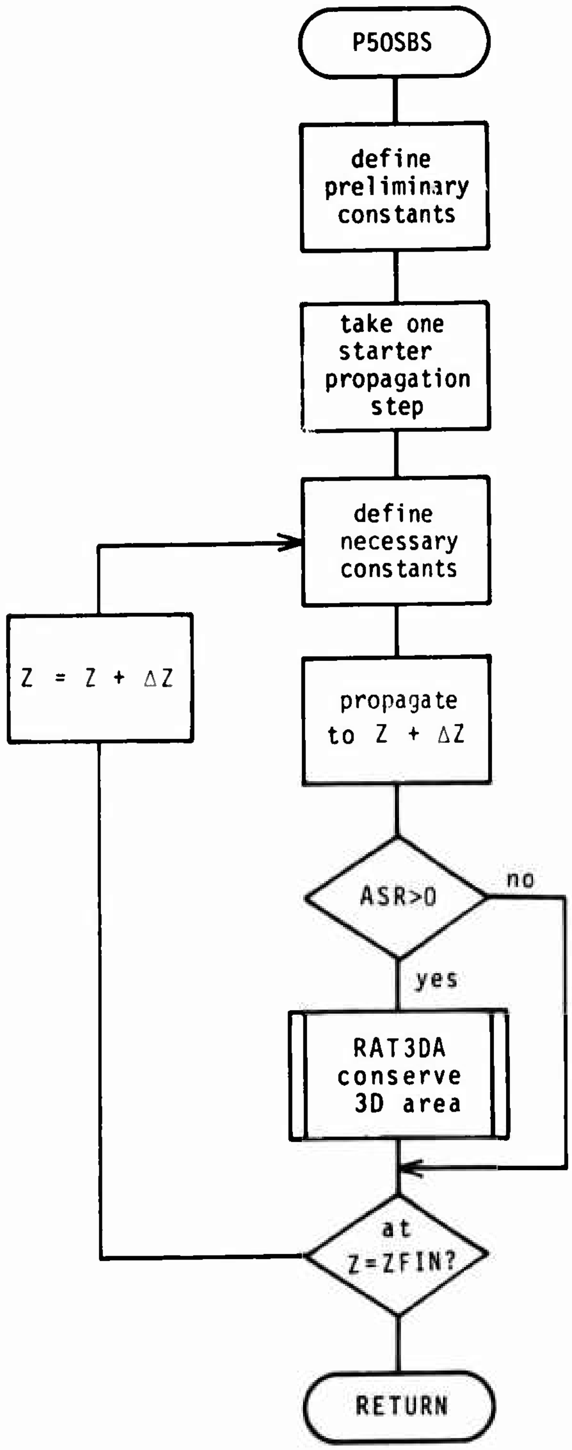


Fig. E4. P50SBS logic flow diagram.

```
      SUBROUTINE P50SBS(NWAVES,NX,NXDIM,XK0,ASR,DXMIR,
     +   VR,DZ,ZSTART,ZFIN,T,U,V)
      COMPLEX T(NXDIM,NWAVES),U(NXDIM,NWAVES),V(NXDIM,NWAVES)
      DIMENSION XK0(NWAVES)
C
C-------------------------------------------------------------
C P50SBS STEP-BY-STEP PROPAGATION OF (NWAVES) WAVEFORMS THROUGH
C                      FREE SPACE USING THE EXPANDING COORDINATE SYSTEM
C                      (ASSUMES CONSTANT DELTA-Z)
C-------------------------------------------------------------
C   THE PARAMETERS ARE
C
C NWAVES THE NUMBER OF PROPAGATING WAVES
C NX     THE NUMBER OF MESH POINTS ALONG X
C NXDIM  THE X-DIMENSION OF THE PROPAGATING MATRICES
C XK0    VECTOR OF K=2*PI/LAMBDA FOR EACH WAVE
C ASR    3D AREA CONSERVATION SWITCH, WHEN .GT. 0
C DXMIR  DELTA-X FOR MIRROR FROM WHICH PROPAGATION IS PROCEEDING
C VR     VIRTUAL RADIUS OF CURVATURE FOR MIRROR (SEE DXPIR)
C DZ     DELTA-Z
C ZSTART DISTANCE FROM LAST MIRROR FOR START OF PROPAGATION
C ZFIN   DISTANCE FROM LAST MIRROR FOR FINISH OF PROPAGATION
C*T      DUMMY VECTOR USED IN PROPAGATING
C*U      WAVE VECTOR SUPPLIED TO AND RETURNED BY SUBPROGRAM
C*V      DUMMY VECTOR USED IN PROPAGATING
C    (* DENOTES A PARAMETER RETURNED IN ALTERED FORM)
C
C   SUBPROGRAMS REQUIREC
C      RAT3DA (3D AREA CONSERVATION ROUTINE)
C
C   8/15/73   CREATED FROM NOTES AND PRPSBS STRUCTURE (PR20)
C
C---------------------------------------------------------------
C
C
C                DEFINE PRELIMINARY CONSTANTS
C
      NXM1=NX-1
      ZLEN=ZFIN-ZSTART
      NZSTEP=ZLEN/DZ+.5
      IF(NZSTEP.LE.0) GC TO 999
      DZZ=ZLEN/FLOAT(NZSTEP)
C
C             TAKE ONE STARTER PROPAGATION STEP
C
C---------DEFINE CONSTANTS DEPENDENT ON Z-POSITION---------
      ZCUR=ZSTART
      DXCUR=DXMIR*(1.+ZCUR/VR)
      F=ZCUR+VR
      AA=1.-DZZ/(2.*F)
C---------------PROPAGATE EACH WAVE TO ZSTART+DZ------------
      DO 150 JWAVE=1,NWAVES
      DELX=DZZ/(XK0(JWAVE)*DXCUR*DXCUR)
      V(1,JWAVE)=0.
      V(NX,JWAVE)=0.
      DO 150 IX=2,NXM1
  150 V(IX,JWAVE)=AA*(U(IX,JWAVE)+.5*DELX*(0.,1.)*(
```

```
     +   U(IX+1,JWAVE)-2.*U(IX,JWAVE)+U(IX-1,JWAVE)))
      IF(NZSTEP.EQ.1) GO TO 999
C
C            TAKE (NZSTEP-1) PROPAGATION STEPS
C
      NZM1=NZSTEP-1
      DO 400 IZ=1,NZM1
C-------------DEFINE CONSTANTS DEPENDENT ON Z-POSITION-----------
      ZCUR=FLOAT(IZ)*DZZ+ZSTART
      DXCUR=DXMIR*(1.+ZCUR/VR)
      F=ZCUR+VR
      AA=1.-DZZ/(2.*F)
C-------------DEFINE CONSTANT DEPENDENT ON WAVE NUMBER----------
      DO 400 JWAVE=1,NWAVES
      DELX=DZZ/(XK0(JWAVE)*DXCUR*DXCUR)
      DELXSQ=DELX*DELX
C---------SHIFT VALUES IN ARRAYS (T=U,  U=V)
      DO 250 IX=1,NX
      T(IX,JWAVE)=U(IX,JWAVE)
  250 U(IX,JWAVE)=V(IX,JWAVE)
C---------PROPAGATE ONE WAVE--------------------
      DO 300 IX=2,NXM1
  300 V(IX,JWAVE)=
     +   AA/(1.+DELXSQ)*
     +   (T(IX,JWAVE)*AA+
     +      (0.,1.)*DELX*(U(IX+1,JWAVE)-2.*T(IX,JWAVE)*AA+U(IX-1,JWAVE))
     +      +DELXSQ*(U(IX+1,JWAVE)-T(IX,JWAVE)*AA+U(IX-1,JWAVE)))
C---------AFTER EACH WAVE HAS ADVANCED DZ, CONSERVE 3D AREA (IF ASR .GT. 0)
      IF(ASR.LE.0.) GO TO 400
      DXNEXT=DXMIR*(1.+(ZCUR+DZ)/VR)
      CALL RAT3DA(NX,NXDIM,NWAVES,DXNEXT,DXCUR,V,U)
  400 CONTINUE
C
C            AT ZFIN, SET U MATRIX TO ENDING VALUES
C
      DO 500 JWAVE=1,NWAVES
      DO 500 IX=1,NX
  500 U(IX,JWAVE)=V(IX,JWAVE)
C
C            RETURN
C
  999 RETURN
      END
```

```
      SUBROUTINE GAINA(NX,NXDIM,IWAVE,SOTOT,GAIN)
      COMPLEX GAIN(NXDIM,IWAVE)
      DIMENSION SOTOT(NXDIM,IWAVE)
      COMMON /CGAINA/ GZERO,XIZERO,XSTART,DXCUR
C
C-------------------------------------------------------------
C   GAINA   ANALYTICAL GAIN ROUTINE
C-------------------------------------------------------------
C   THE PARAMETERS ARE
C
C NX-----NUMBER OF X POINTS
C NXDIM--DIMENSION (IN X) OF SOTOT
C IWAVE--NUMBER OF PROPAGATIONG WAVES
C SOTOT--SUMMED INTENSITIES MATRIX
C GAIN---GAIN MATRIX (RETURNED)
C GZERO  SMALL SIGNAL GAIN
C XIZERO SATURATION FLUX DENSITY
C XSTART X-LOCATION (RELATIVE TO NOZZLE BANK) OF 1ST INTENSITY ELEMENT
C DXCUR  DELTA-X FOR INTENSITY MATRIX
C
C   SUBPROGRAMS REQUIRED--NONE
C
C-------------------------------------------------------------
C
      DO 100 JWAVE=1,IWAVE
      DO 100 I=1,NX
100   GAIN(I,JWAVE)=GZERO/(1.+SOTOT(I,JWAVE)/XIZERO)
      RETURN
      END
```

```
      SUBROUTINE MIRROR(IWAVE,NX,NXDIM,U,V,XM)
      COMPLEX U(NXDIM,IWAVE),XM(NX),V(NX),A
      XMGTD(A)=SQRT(REAL(A)**2+AIMAG(A)**2)
C
C-----------------------------------------------------------
C---MIRROR--MULTIPLIES MIRROR MATRIX TIMES PROPAGATION MATRIX
C
C   THE PARAMETERS ARE
C IWAVE--THE NUMBER OF PROPAGATING WAVES
C NX-----THE NUMBER OF X POINTS
C NXDIM--THE X-DIMENSION OF THE PROPAGATION MATRIX
C U------INPUT/REFLECTED WAVE MATRIX (COMPLEX)
C V------DUMMY VECTOR (COMPLEX, DIM. AT LEAST NX)
C XM-----MIRROR VECTOR (COMPLEX, DIM. AT LEAST NX)
C
C   SUBPROGRAMS REQUIRED--NONE
C
C   CHANGED 3-26-73 (END POINTS DEFINED)
C
C-----------------------------------------------------------
C
      NXM1=NX-1
      DO 230 JWAVE=1,IWAVE
      DO 220 I=2,NXM1
      AVGMAG=.25*XMGTD(U(I-1,JWAVE))+.5*XMGTD(U(I,JWAVE))+
     +   .25*XMGTD(U(I+1,JWAVE))
      UREAL=REAL(U(I,JWAVE))
      UIMAG=AIMAG(U(I,JWAVE))
      IF(UREAL.EQ.0.) URP=0.
      IF(UREAL.NE.0.) URP=SIGN(1.,UREAL)*
     +   AVGMAG/SQRT((UIMAG/UREAL)**2+1.)
      IF(UIMAG.EQ.0.) UIP=0.
      IF(UIMAG.NE.0.) UIP=SIGN(1.,UIMAG)*
     +   AVGMAG/SQRT((UREAL/UIMAG)**2+1.)
      V(I)=CMPLX(URP,UIP)*XM(I)
  220 CONTINUE
      V(1)=U(1,JWAVE)*XM(1)
      V(NX)=U(NX,JWAVE)*XM(NX)
      DO 230 I=1,NX
      U(I,JWAVE)=V(I)
  230 CONTINUE
      RETURN
      END
```

SUBROUTINE NORM2D   74/74   OPT=1   FTN 4.6+P357   09/27/73 14.14.24.   PAGE   1

```
      SUBROUTINE NORM2D(IFILE,NX,NXDIM,IWAVE,DX,U)
      COMPLEX U(NXDIM,IWAVE)
C
C--------------------------------------------------------------
C   NORM2D   2D NORMALIZATION ROUTINE
C
C   THE PARAMETERS ARE--
C
C IFILE--
C   .LE.0  NORMALIZE, DON'T PRINT
C   .GT.0  NORMALIZE, PRINT PARAMETERS ON FILE CODE IFILE
C NX-----NUMBER OF X POINTS
C NXDIM--X DIMENSION OF PROPAGATION ARRAY
C IWAVE--NUMBER OF PROPAGATING WAVES
C DX-----DELTA-X FOR MESH SPACING
C U------PROPAGATION MATRIX (COMPLEX, DIM NXDIM BY IWAVE)
C
C   SUBROUTINES NECESSARY--AREA21
C
C   8/29/73   DELTA-X ARGUMENT SUBSTITUTED FOR X-ARRAY
C--------------------------------------------------------
C
      DO 500 JWAVE=1,IWAVE
      CALL AREA21(0,NX,NXDIM,1,2,1,1HX,DX,U(1,JWAVE),0.,AREA2D,A3)
      GAMMA=SQRT(AREA2D)
      XLOSS=1.-AREA2D
      DO 150 I=1,NX
150   U(I,JWAVE)=U(I,JWAVE)/GAMMA
500   IF(IFILE.GT.0) WRITE(IFILE,9000)  JWAVE,XLOSS,AREA2D
 9000 FORMAT(1H0,29H2D NORMALIZATION, WAVE NUMBER,I3/
     +    5X,4HLOSS,E20.7/5X,17HAREA BEFORE NORM.,E20.7)
      RETURN
      END
```

```
      SUBROUTINE PWROUT(IFILE,NX,NX2,ASR,DX,OMEGA,TLOSS,REFL,
     +   U,PWRNF,PWROT)
      COMPLEX U(NX),A
      XINTY(A)=REAL(A)**2+AIMAG(A)**2
C
C------------------------------------------------------------
C   PWROUT--FOR ONE WAVE, COMPUTES POWER BEFORE AND AFTER MIRROR
C
C  THE PARAMETERS ARE
C
C IFILE--PRINT OPTION
C    .LE. 0   DON'T PRINT
C    .GT. 0   PRINT POWER AT MIRROR, POWER OUT, AND POWER
C             DIFFERENCE ON FILE CODE IFILE
C NX-----THE NUMBER OF X POINTS
C NX2----THE NUMBER OF INTERVALS ACROSS THE OUTPUT MIRROR FLAT
C ASR----3D AREA ADJUSTMENT FACTOR
C    .EQ. 0.   2D POWER COMPUTATION
C    .NE. 0.   3D POWER COMPUTATION
C DX-----DELTA X FOR PROPAGATION VECTOR
C OMEGA--MIRROR EDGE FALLOFF PARAMETER FOR OUTPUT MIRROR
C TLOSS--POWER LOSS OF MIRROR (DECIMAL FRACTION)
C REFL---POWER REFLECTIVITY OF MIRROR
C U------PROPAGATION VECTOR (COMPLEX, DIM AT LST NX)
C PWRNF--POWER BEFORE OUTPUT MIRROR
C PWROT--POWER AFTER OUTPUT MIRROR
C
C   SUBPROGRAMS REQUIRED--NONE
C
C   CHANGED 3-26-73 (CALL TO AREA REMOVED, 2D/3D MADE OPTION)
C   8/29/73    REFERENCE TO X-ARRAY DELETED
C
C------------------------------------------------------------
C
      CONST=(1.-REFL)*(1.-TLOSS)
      ICENT=(NX+1)/2
      PWRNF=0.
      PWROT=0.
      FFDIA=FLOAT(NX2)*DX+2.*OMEGA
C----------COMPUTE NEAR FIELD POWER AND POWER OUT-------------
      DO 215 I=1,NX
      XDEL=ABS(FLOAT(ICENT-I)*DX)
      IF(ASR.EQ.0.) PSX=XINTY(U(I))*DX
      IF(ASR.NE.0.) PSX=XDEL*XINTY(U(I))*DX
      PWRNF=PWRNF+PSX
      IF(2.*XDEL.LT.FFDIA) PWROT=PWROT+CONST*PSX
      IF (2.*XDEL.GE.FFDIA) PWROT=PWROT+PSX
  215 CONTINUE
C---------ADJUST FOR 3D FACTOR, IF NECESSARY-------------
      IF(ASR.NE.0.) PWRNF=ASR*PWRNF
      IF(ASR.NE.0.) PWROT=ASR*PWROT
C----------PRINT RESULTS, IF DESIRED-------------
      PWRDEL=PWRNF-PWROT
      IF(IFILE.GT.0) WRITE(IFILE,1000) PWRNF,PWROT,PWRDEL
 1000 FORMAT(1H0,5HPOWER/5X,17HNEAR FIELD POWER=,E20.7/
     +   5X,26HOUTPUT POWER AFTER MIRROR=,E20.7/5X,17HPOWER DIFFERENCE=,
     +   E20.7)
```

```
      RETURN                                                            5720
      END                                                               5740
```

```
      SUBROUTINE RAT3DA(NX,NXDIM,IWAVE,DXU,DXV,U,V)
      COMPLEX U(NXDIM,IWAVE),V(NXDIM,IWAVE)
      DIMENSION A(2)
      COMMON /RCUM/ RCUM3D(1)
C
C-----------------------------------------------------------------
C   RAT3DA--MODIFIES PROPAGATION MATRIX AT EACH DZ STEP TO
C          CONSERVE 3D AREA
C
C  THE PARAMETERS ARE
C NX-----THE NUMBER OF X POINTS
C NXDIM--THE X-DIMENSION OF THE PROPAGATION MATRIX
C IWAVE  THE NUMBER OF PROPAGATING WAVES
C DXU----DELTA-X FOR THE U-MATRIX
C DXV----DELTA-X FOR THE V-MATRIX
C U------PROPAGATION MATRIX (COMPLEX, DIM NXDIM BY IWAVE)
C V------PREVIOUS STEP PROPAGATION MATRIX (COMPLEX, DIM NXDIM BY IWAVE)
C RCUM3D-CUMULATIVE RATIOS FOR EACH WAVE (REAL, DIM AT LST IWAVE)
C
C   SUBPROGRAMS REQUIRED--NONE
C
C   8/30/73   2 DX VARIABLES SUBSTITUTED FOR X-ARRAY
C---------------------------------------------------------------------
C
      DO 100 JWAVE=1,IWAVE
      A(1)=0.
      A(2)=0.
      ICENT=(NX+1)/2
      DO 50 I=1,NX
      XDELU=ABS(FLOAT(I-ICENT)*DXU)*DXU
      XDELV=ABS(FLOAT(I-ICENT)*DXV)*DXV
      A(1)=A(1)+(REAL(U(I,JWAVE))**2+AIMAG(U(I,JWAVE))**2)*XDELU
50    A(2)=A(2)+(REAL(V(I,JWAVE))**2+AIMAG(V(I,JWAVE))**2)*XDELV
      RATIO=SQRT(A(2)/A(1))
      RCUM3D(JWAVE)=RCUM3D(JWAVE)*RATIO
      DO 100 I=1,NX
      U(I,JWAVE)=U(I,JWAVE)*RATIO
      V(I,JWAVE)=V(I,JWAVE)*RATIO
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SETMIR(NX,NX2,DX,XK0,REFL,RCURV,OMEGA,BETA,XM)
      COMPLEX XM(NX),CURV,TILT
C
C-----------------------------------------------------------------
C   SETMIR---SETS UP A MIRROR VECTOR
C
C   THE PARAMETERS ARE
C NX-----THE NUMBER OF X-POINTS ACROSS THE MIRROR
C NX2----THE NUMBER OF INTERVALS ACROSS THE
C        MIRROR CENTER NOT SUBJECT TO THE NORMAL FALLOFF EFFECT
C DX-----DELTA X
C XK0----K = 2 PI / LAMBDA
C REFL--MIRROR REFLECTIVITY (POWER)-
C RCURV--MIRROR RADIUS OF CURVATURE
C OMEGA--MIRROR EDGE FALLOFF PARAMETER
C BETA---MIRROR TILT ANGLE
C XM-----MIRROR VECTOR (COMPLEX, DIM. AT LST NX)
C
C   SUBPROGRAMS REQUIRED--NONE
C
C   CHANGED 2-8-73,3-1-73,3-20-73
C   7/25/73   REMOVED FAR FIELD CAPABILITY AND X DEFINITION
C   8/29/73   REFERENCE TO X-ARRAY DELETED
C----------------------------------------------------------------
C
      ICENT=(NX+1)/2
      NX2P=NX2-MOD(NX2,2)
      NX1=(NX-NX2P-1)/2
C
C          DEFINE MIRROR VALUE FOR EACH MATRIX LOCATION
C
      DO 140 J=1,NX
      XDEL=FLOAT(J-ICENT)*DX
C------------DETERMINE RADIUS OF CURVATURE COMPONENT---------
      IF(RCURV.GE.(1.E30)) CURV=1.
      IF(RCURV.LT.(1.E30)) CURV=
     +   CEXP(-XK0*XDEL**2*(0.,1.)/RCURV)
C-----------DETERMINE MIRROR TILT COMPONENT----------------
      TILT=CEXP(2.*XK0*BETA*XDEL*(0.,1.))
C----------DETERMINE EDGE FALLOF COMPONENT-------------
      FALLOF=0.
      IF(J.GE.(NX1+1).AND.J.LE.(NX1+NX2P+1)) FALLOF=1.
      IF(OMEGA.EQ.0.) GO TO 130
      IF(J.LE.NX1) FALLOF=
     +   EXP(-(FLOAT((NX1+1)-J)*DX/OMEGA)**2)
      IF(J.GE.(NX1+NX2P+2)) FALLOF=
     +   EXP(-(FLOAT(J-(NX1+NX2P+1))*DX/OMEGA)**2)
C-------------COMPUTE MIRROR VECTOR VALUE-----------------
  130 XM(J)=SQRT(REFL)*FALLOF*CURV*TILT
  140 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE AREA21(IFILE,NPTS,NXDIM,NWAVES,ICMPLX,NCHAR,           18080
     +   TITLE,DX,S,ASR,AREA2D,AREA3D)                                  18100
      DIMENSION S(ICMPLX,NXDIM,NWAVES),TITLE(1)                         18120
C                                                                       18140
C-------------------------------------------------------------          18160
C   AREA21    COMPUTES AREAS FOR REAL OR COMPLEX MATRIX                 18180
C---------------------------------------------------------------------  18200
C THE PARAMETERS ARE                                                    18220
C                                                                       18240
C IFILE--OUTPUT FILE CODE                                               18260
C   .LE. 0   DON'T PRINT AREAS                                          18280
C   .GT. 0   PRINT TITLE AND AREA(S) SUMMARY                            18300
C NPTS    NUMBER OF POINTS ALONG X IN MATRIX                            18320
C NXDIM  THE FIRST (OR X-) DIMENSION OF THE MATRIX                      18340
C NWAVES THE NUMBER OF PROPAGATING WAVES                                18360
C ICMPLX-REAL/COMPLEX MATRIX OPTION                                     18380
C   .EQ. 1   INPUT MATRIX IS REAL                                       18400
C   .EQ. 2   INPUT MATRIX IS COMPLEX (USE INTENSITIES)                  18420
C NCHAR  THE NUMBER OF CHARACTERS IN THE TITLE SUPPLIED                 18440
C TITLE  THE HOLLERITH CR BCD TITLE TO BE PRINTED                       18460
C DX-----DELTA-X FOR MESH SPACING                                       18480
C S------INPUT MATRIX FCR WHICH AREA IS DESIRED                         18500
C ASR     3D AREA MULTIPLIER                                            18520
C AREA2D 2D AREA (RETURNED)                                             18540
C AREA3D 3D AREA (RETURNED)                                             18560
C                                                                       18580
C   SUBPROGRAMS REQUIREC--NONE                                          18600
C                                                                       18620
C   7/23/73   CREATED FROM @AREA@                                       18640
C   8/23/73   3D AREA FIX--STMT 100 + 2 MULTIPLIED BY ASR               18660
C   8/29/73   DELTA-X ARGUMENT SUBSTITUTED FOR X-ARRAY                  18680
C                                                                       18700
C-------------------------------------------------------------          18720
C                                                                       18740
C----------SETUP NECESSARY VARIABLES--------------                      18760
      ICENT=(NPTS+1)/2                                                  18780
      INORDS=(NCHAR-1)/10+1
      IF(IFILE.GT.0) WRITE(IFILE,9050) (TITLE(I),I=1,INORDS)            18820
C                                                                       18840
C         COMPUTE AREAS FOR EACH WAVE                                   18860
C                                                                       18880
      DO 500 IWAVE=1,NWAVES                                             18900
      AREA2D=0.                                                         18920
      AREA3D=0.                                                         18940
C-------------COMPUTE 2D AND 3D AREAS----------------                   18960
      DO 100 I=1,NPTS                                                   18980
      XDEL=ABS(FLOAT(I-ICENT)*DX)                                       19000
      IF(ICMPLX.EQ.1) VAL=S(1,I,IWAVE)                                  19020
      IF(ICMPLX.EQ.2) VAL=S(1,I,IWAVE)**2+S(2,I,IWAVE)**2               19040
      AREA2D=AREA2D+VAL                                                 19060
      AREA3D=AREA3D+VAL*XDEL                                            19080
  100 CONTINUE                                                          19100
      AREA2D=AREA2D*DX                                                  19120
      AREA3D=AREA3D*DX*ASR                                              19140
C--------PRINT RESULTS IF DESIRED------------                           19160
      IF(IFILE.LE.0) GO TO 500                                          19180
      IF(ASR.GT.0.) WRITE(IFILE,9000) AREA3D                            19200
```

```
          IF(ASR.LE.0.) WRITE(IFILE,9010) AREA2D                   19220
     9000 FORMAT(5X,7H3D AREA,E20.7)                               19240
     9010 FORMAT(5X,7H2D AREA,E20.7)                               19260
     9050 FORMAT(1H0,7A10)
     500  CONTINUE                                                 19300
     999  RETURN                                                   19320
          END                                                      19340
```

```
      SUBROUTINE RSTART(IFILE,IRCODE,IRTAG,NWAVES,NXDIM,NZDIM,          19400
     +   U,SO)                                                           19420
      DIMENSION IDUM(10),RDUM(10)                                        19440
      DIMENSION SO(101,21,2)
      COMPLEX U(101,2)
      COMMON /FFNZ/ NZ                                                   19500
C-----------------------------------------------------------------       19520
C   RSTART---READS RESTART TAPE FOR PR SERIES                            19540
C-------------------------------------------------------------           19560
C   THE PARAMETERS ARE                                                   19580
C                                                                        19600
C IFILE--FILE CODE FOR SUMMARIZING RESTART PARAMETERS                    19620
C      .LE. 0    DON'T PRINT                                             19640
C      .GT. 0    PRINT PARAMETERS ON FILE CODE IFILE                     19660
C IRCODE-FILE CODE FROM WHICH RESTART PARAMETERS ARE TO BE READ          19680
C IRTAG--A TAG PARAMETER WHICH THE RESTART ROUTINE WILL SEARCH FOR       19700
C NWAVES-THE NUMBER OF WAVES TO BE TAKEN FROM RESTART FILE               19720
C NXDIM--THE X DIMENSION OF BOTH THE U AND SO MATRICES                   19740
C NZDIM--THE Z DIMENSION OF THE SO MATRIX                                19760
C U------THE PROPAGATION MATRIX TO BE FILLED FROM RESTART FILE           19780
C SO-----THE PAST INTENSITIES MATRIX TO BE FILLED FROM RST. FILE         19800
C                                                                        19820
C   SUBPROGRAMS REQUIRED--NONE                                           19840
C                                                                        19860
C   CHANGED 1-25-73                                                      19880
C   CHANGED 9/6/73    SPECIAL COMMON FOR RETURN OF NZ VALUE              19900
C                                                                        19920
C------------------------------------------------------------------      19940
C                                                                        19960
C-------READ IDENTIFICATION LABEL OF RESTART TAPE-------------           19980
C                                                                        20000
      REWIND IRCODE                                                      20020
      READ(IRCODE) TIME,DATE,SNMB,PROG,CASE                              20040
 1000 FORMAT(1X,5A6)                                                     20060
      IF(IFILE.GT.0) WRITE(IFILE,1010)  IRCODE,IRTAG,TIME,               20080
     +   DATE,SNMB,PROG,CASE                                             20100
 1010 FORMAT(1H1,29HUSING RESTART TAPE, FILE CODE , I5,                  20120
     +   11H, TO MATCH  ,I6/1H0,5X,19HTAPE IDENTIFICATION /10X,4HTIME,   20140
     +   5X,A6/10X,4HDATE,5X,A6/10X,5HSNUMB,4X,A6/10X,7HPROGRAM,         20160
     +   2X,A6/10X,4HCASE,5X,F6.1)                                       20180
C                                                                        20200
C-----------READ GOVERNING PARAMETERS FOR STORED INFORMATION------       20220
C                                                                        20240
      READ(IRCODE) IDUM,RDUM                                             20260
      NX=IDUM(1)                                                         20280
      NZ=IDUM(2)                                                         20300
      IWAVE=IDUM(3)                                                      20320
      IF(IFILE.GT.0) WRITE(IFILE,1020)  NX,NZ,IWAVE                      20340
 1020 FORMAT(1H0,41HGOVERNING PARAMETERS FOR TAPE INFORMATION /          20360
     +   5X,3HNX=,I5/5X,3HNZ=,I5/5X,6HIWAVE=,I5)                         20380
C                                                                        20400
C----------FIND INDICATED TAG FIELD AND READ INFORMATION-------          20420
C                                                                        20440
  100 READ(IRCODE) ITAG                                                  20460
      READ(IRCODE) ((U(I,J),I=1,NX),J=1,NWAVES)                          20480
      READ(IRCODE) (((SO(I,J,K),I=1,NX),J=1,NZ),K=1,NWAVES)              20500
      IF(EOF(IRCODE)) 999,200
```

```
      200  IF(ITAG.NE.IRTAG) GO TO 100
      999  RETURN                                        20560
           END
```

```
      SUBROUTINE CSCALE(X,SX,NP,KCYC,NNVAL,AA,ZMIN,DZ)
      DIMENSION A(6),X(NP),AA(1)
      DATA NVAL,A(1),A(2),A(3),A(4),A(5),A(6)/6,1.,2.,4.,5.,8.,10./
C---------------------------------------------------------------
C---------THE INPUT PARAMETERS ARE--
C-X-------THE ARRAY TO BE SCALED
C-SX------THE NUMBER OF INTERVALS IN WHICH TO DIVIDE X
C-NP------THE NUMBER OF POINTS IN X
C-KCYC----SKIP PARAMETER FOR X
C-NNVAL----
C    .LE.0---TAKE DEFAULT SCALING PARAMETERS
C    .GT.0---SUBSTITUTE THE NVAL OTHER VALUES IN ARRAY AA
C-AA------SUBSTITUTE SCALING PARAMETERS
C-ZMIN----SCALED MINIMUM FOR X
C-DZ------SCALED INTERVAL WIDTH FOR X
C---------------------------------------------------------------
C---------SET UP SCALING ARRAY------------
     IF(NNVAL.LE.0) GO TO 50
     DO 30 I=1,NNVAL
30   A(I)=AA(I)
     NVAL=NNVAL
50   CONTINUE
C------DEFINE DX AND RANGE FOR DATA
      XMIN=1.E30
      XMAX=-1.E30
      DO 100 I=1,NP,KCYC
      XMIN=AMIN1(XMIN,X(I))
 100  XMAX=AMAX1(XMAX,X(I))
      RANGE=XMAX-XMIN
      DX=RANGE/SX
C-------DEFINE ORDER OF MAGNITUDE OF DX
      IDEL=1
      IF(ABS(DX).LT.1.) IDEL=-1
      DO 110 J=1,31
      I=(J-1)*IDEL
      DZX=DX/10.**I
      IF(DZX.GE.(1.).AND.DZX.LT.(10.))
    1 GO TO 120
 110 CONTINUE
 120  IC=I
C-------DEFINE DZ AND ZMIN
 200  Y=10.**IC
      DO 230 I=1,NVAL
      DZ=A(I)*Y
      IF(XMIN.GE.0.) ZMIN=AINT(XMIN/Y)*Y
      IF(XMIN.LT.0.) ZMIN=AINT(XMIN*(1.-1.E-4*DZ)/Y-1.)*Y
      ZMAX=ZMIN+SX*DZ
      IF(DZ.GE.DX.AND.ZMAX.GE.(XMAX-1.E-4*DZ))
    1 GO TO 250
 230 CONTINUE
      IC=IC+1
      GO TO 200
 250  RETURN
      END
```

```
      SUBROUTINE PGPLT2(IFILE,ISCALE,N,ICYC,NCHAR,LABEL,
     + X,NXCHAR,LABELX,Y,NYCHAR,LABELY)
      DIMENSION X(1),Y(1),LABEL(1),LABELX(1),LABELY(1)
      DIMENSION VAL(12),Z(111)
      DATA BLANK,PLUS/1H ,1H+/
C
C------------------------------------------------------------
C  PGPLT2---PAGE PLOT ROUTINE WITH SCALING OPTION
C
C  THE PARAMETERS ARE
C
C IFILE  FILE CODE FOR PLOT
C ISCALE-SCALING OPTION
C   .EQ.0  FULL PAGE PLCT, NO AXIS SCALING
C   .EQ.1  AXIS SCALING FOR CONVENIENT SCALE
C N------NUMBER OF POINTS IN X AND Y ARRAYS
C ICYC---CYCLE PARAMETER FOR ARRAYS (I=1,N,ICYC)
C NCHAR--NUMBER OF CHARS IN TITLING ARRAY (LABEL)
C LABEL--TITLING ARRAY FOR PAGE PLOT
C X------X ARRAY (INDEPENDENT VARIABLE)
C NXCHAR-NUMBER OF CHARS IN X-AXIS LABEL
C LABELX-X AXIS LABEL
C Y------Y ARRAY (DEPENDENT VARIABLE)
C NYCHAR-NUMBER OF CHARS IN Y AXIS LABEL
C LABELY-Y AXIS LABEL
C
C   SUBPROGRAMS REQUIREC--CSCALE
C
C   8/29/73   VERTICAL REGISTRATION PROBLEM FIXED ON Y-AXIS
C   8/29/73   NULL PLOT LOGIC INSERTED BEFORE STMT 200
C-------------------------------------------------------------
C
C----------TITLE PLOT----------------
      NWORDS=MIN0((NCHAR-1)/10+1,5)
      NXWORD=MIN0((NXCHAR-1)/10+1,3)
      NYWORD=MIN0((NYCHAR-1)/10+1,3)
      IF(NWORDS.GT.0) WRITE(IFILE,3000) (LABEL(I),I=1,NWORDS)
      IF(NWORDS.LE.0) WRITE(IFILE,3010)
C
C---------ESTABLISH SCALING PARAMETERS---------------
C
      IF(ISCALE.LE.0) GC TO 100
C-----------CHOOSE CONVENIENT SCALES---------------
      CALL CSCALE(X,11.,N,ICYC,0,0,XLO,XINC)
      XRANGE=11.*XINC+XINC/10.
      RANGE=11.*XINC
      XINC=XINC/10.
      CALL CSCALE(Y,5.,N,ICYC,0,0,YLO,YINC)
      YRANGE=5.*YINC
      YINC=YINC/10.
      GO TO 200
C-----------USE WHOLE PAGE--------------
100   XLO=1.E30
      XHI=-1.E30
      YLO=1.E30
      YHI=-1.E30
      DO 150 I=1,N,ICYC
```

```
      XLO=AMIN1(XLO,X(I))
      XHI=AMAX1(XHI,X(I))
      YLO=AMIN1(YLO,Y(I))
  150 YHI=AMAX1(YHI,Y(I))
      XINC=(XHI-XLO)/110.
      YINC=(YHI-YLO)/50.
      XRANGE=XHI-XLO+XINC
      RANGE=XHI-XLO
      YRANGE=YHI-YLO
      IF(YHI*YLO.EQ. 0. .OR. YHI*.9999.GT.YLO) GO TO 200
      WRITE(IFILE,1500) YLO,YHI
      GO TO 999
  200 WRITE(IFILE,1000) N,XINC,YINC,(LABELY(I),I=1,NYWORD)
C
C----------PRODUCE PGPLCT-------------
C
      YCURM=YRANGE+YLO+YINC/2.
      DO 300 IJ=1,51
      YCUR=(51.-FLOAT(IJ))/50.*YRANGE+YLO
      YCURP=YCURM
      YCURM=YCURP-YINC
  250 DO 270 I=1,111
  270 Z(I)=BLANK
      DO 280 I=1,N
      IF(Y(I).GT.YCURP.OR.Y(I).LE.YCURM) GO TO 280
      INT=111.*(X(I)-XLO+XINC/2.)/XRANGE+1.
      Z(INT)=PLUS
  280 CONTINUE
      K=MOD((IJ-1),5)
      IF(K.EQ.0) WRITE(IFILE,1300) YCUR,Z
      IF(K.NE.0) WRITE(IFILE,1350) Z
  300 CONTINUE
C--------------COMPLETE LOWER AXIS LABELING-------------
      DO 400 I=1,6
  400 VAL(I)=XLO+2.*FLOAT(I-1)*RANGE/11.
      DO 450 I=7,12
  450 VAL(I)=XLO+(2.*FLOAT(I-7)+1.)*RANGE/11.
      WRITE(IFILE,1400) VAL,(LABELX(I),I=1,NXWORD)
  999 RETURN
 3000 FORMAT(1H1,5A10)
 3010 FORMAT(1H1)
 1000 FORMAT(1X,17HNUMBER OF POINTS=,I4,15X,12HX INCREMENT=,
     +   E16.8,12X,12HY INCREMENT=,E16.8//5X,3A10)
 1300 FORMAT(1X,E16.8,3H - ,111A1)
 1350 FORMAT(18X,2H1 ,111A1)
 1400 FORMAT(20X,11(1H1,9H---------),1H1/
     +   8X,6E20.8/17X,5E20.8,E14.6//76X,3A10)
 1500 FORMAT(1X,25(/1X),34HY-AXIS VALUES ARE APPROX. CONSTANT ,
     +   8H BETWEEN , E20.7, 4H AND , E20.7, 25(/1X))
      END
```

```
FUNCTION VALUE       74/74    OPT=1                          FTN 4.6+P357        09/27/73  14.22.46.        PAGE     1

      FUNCTION VALUE(ITYPE,GLOC)
      DIMENSION GLOC(2)
C
C-----------------------------------------------------------------
C-VALUE---RETURNS ONE OF SEVERAL VALUES
C   THE PARAMETERS ARE
C ITYPE---OPTION IDENTIFYING TYPE OF VALUE TO BE RETURNED
C    =0 THE VALUE OF GLOC(1)
C    =1 REAL, OR THE VALUE OF GLOC(1)
C    =2 IMAGINARY, OR THE VALUE OF GLOC(2)
C    =3 MAGNITUDE OF GLOC ASSUMING GLOC COMPLEX NUMBER
C    =4 INTENSITY OF GLOC ASSUMING GLOC COMPLEX NUMBER
C    =5 PHASE ANGLE (RADIANS, -PI TO +PI) OF GLOC
C    =6 PHASE ANGLE (DEGREES, -180 TO +180) OF GLOC
C GLOC--SUPPLIED MATRIX ELEMENT FOR WHICH THE VALUE IS TO BE FOUND
C
C   SUBPROGRAMS REQUIRED--NONE
C
C-----------------------------------------------------------------
C
      IF(ITYPE.GT.1) GO TO 100
10    VALUE=GLOC(1)
      RETURN
100   GO TO (10,120,130,140,150,150), ITYPE
120   VALUE=GLOC(2)
      RETURN
130   VALUE=SQRT(GLOC(1)**2+GLOC(2)**2)
      RETURN
140   VALUE=GLOC(1)**2+GLOC(2)**2
      RETURN
150   VALUE=-.5
      IF(GLOC(1).NE.0..OR.GLOC(2).NE.0.)
     +   VALUE=ATAN2(GLOC(2),GLOC(1))
      IF(ITYPE.EQ.6.AND.VALUE.NE.(-.5)) VALUE=VALUE*57.296
      RETURN
      END
```

```
      SUBROUTINE ALLOUT(IFILE,NPTS,ISKIP,NMAT,NCHAR,LABEL,                    6680
     +  IC1,IO1,NC1,LBL1,A1,B1,IC2,IO2,NC2,LBL2,A2,B2,                        6700
     +  IC3,IO3,NC3,LBL3,A3,B3,IC4,IO4,NC4,LBL4,A4,B4,                        6720
     +  IC5,IO5,NC5,LBL5,A5,B5,IC6,IO6,NC6,LBL6,A6,B6,                        6740
     +  IC7,IO7,NC7,LBL7,A7,B7)                                               6760
*ALLOUT     OUTPUT ROUTINE FOR MULTIPLE ARRAYS                                6660
      DIMENSION A1(IC1,NPTS),A2(IC2,NPTS),A3(IC3,NPTS),                       6780
     +  A4(IC4,NPTS),A5(IC5,NPTS),A6(IC6,NPTS),A7(IC7,NPTS)                   6800
      DIMENSION B1(NPTS),B2(NPTS),B3(NPTS),B4(NPTS),B5(NPTS),                 6820
     +  B6(NPTS),B7(NPTS)                                                     6840
      DIMENSION LBL1(1),LBL2(1),LBL3(1),LBL4(1),LBL5(1),                      6960
     +  LBL6(1),LBL7(1),LABEL(1)                                              6880
      DIMENSION CVAL(7),INDEX(7,7),IVAL(7),ILBL(21)                           6900
      IOPT(IWORD,N)=MOD(IWORD/10**(N-1),10)                                   6920
C-----------SET UP INDICES FOR OPTIONS-------------                           6940
      DO 2 I=1,7                                                              6960
      DO 2 J=1,7                                                              6980
    2 INDEX(I,J)=0                                                            7000
      DO 4 I=1,7                                                              7020
      IF(NMAT.GE.1) INDEX(I,1)=IOPT(IO1,I)                                    7040
      IF(NMAT.GE.2) INDEX(I,2)=IOPT(IO2,I)                                    7060
      IF(NMAT.GE.3) INDEX(I,3)=IOPT(IO3,I)                                    7080
      IF(NMAT.GE.4) INDEX(I,4)=IOPT(IO4,I)                                    7100
      IF(NMAT.GE.5) INDEX(I,5)=IOPT(IO5,I)                                    7120
      IF(NMAT.GE.6) INDEX(I,6)=IOPT(IO6,I)                                    7140
    4 IF(NMAT.GE.7) INDEX(I,7)=IOPT(IO7,I)                                    7160
C----------------SET UP MATRICES FOR OUTPUT----------------                   7180
      IF(NMAT.GE.1) CALL ONEOUT(IC1,NPTS,ISKIP,INDEX(1,1),A1,B1)              7200
      IF(NMAT.GE.2) CALL ONEOUT(IC2,NPTS,ISKIP,INDEX(1,2),A2,B2)              7220
      IF(NMAT.GE.3) CALL ONEOUT(IC3,NPTS,ISKIP,INDEX(1,3),A3,B3)              7240
      IF(NMAT.GE.4) CALL ONEOUT(IC4,NPTS,ISKIP,INDEX(1,4),A4,B4)              7260
      IF(NMAT.GE.5) CALL ONEOUT(IC5,NPTS,ISKIP,INDEX(1,5),A5,B5)              7280
      IF(NMAT.GE.6) CALL ONEOUT(IC6,NPTS,ISKIP,INDEX(1,6),A6,B6)              7300
      IF(NMAT.GE.7) CALL ONEOUT(IC7,NPTS,ISKIP,INDEX(1,7),A7,B7)              7320
C                                                                             7340
C---------------PRINT SPECIFIED MATRICES----------------                      7360
C                                                                             7380
      NCOL=0                                                                  7400
      DO 30 I=1,NMAT                                                          7420
      IF(INDEX(2,I).LE.0) GO TO 30                                            7440
      NCOL=NCOL+1                                                             7460
      IVAL(NCOL)=I                                                            7480
   30 CONTINUE                                                                7500
      IF(NCOL.LE.0) GO TO 300                                                 7520
C--------------POSITION COLUMN HEADINGS------------------                     7540
      DO 40 I=1,NCOL                                                          7560
      J=IVAL(I)                                                               7580
      ISTRT=(I-1)*2+1                                                         7600
      IF(J.EQ.1) CALL LBLPOS(NC1,LBL1,ISTRT,ILBL)                             7620
      IF(J.EQ.2) CALL LBLPOS(NC2,LBL2,ISTRT,ILBL)                             7640
      IF(J.EQ.3) CALL LBLPOS(NC3,LBL3,ISTRT,ILBL)                             7660
      IF(J.EQ.4) CALL LBLPOS(NC4,LBL4,ISTRT,ILBL)                             7680
      IF(J.EQ.5) CALL LBLPOS(NC5,LBL5,ISTRT,ILBL)                             7700
      IF(J.EQ.6) CALL LBLPOS(NC6,LBL6,ISTRT,ILBL)                             7720
   40 IF(J.EQ.7) CALL LBLPOS(NC7,LBL7,ISTRT,ILBL)                             7740
C--------------PRINT LINES---------------------                               7760
      LINES=0                                                                 7780
```

```
      DO 100 I=1,NPTS,ISKIP
      IF(MOD(LINES,50).NE.0) GO TO 50
      NWORDS=(NCHAR-1)/10+1
      IF(NWORDS.GT.8) WRITE(IFILE,1000) (LABEL(K),K=1,NWORDS)
      IF(NWORDS.LE.8) WRITE(IFILE,1010)
      KMAX=2*NCOL
      WRITE(IFILE,1020) (ILBL(K),K=1,KMAX)
   50 LINES=LINES+1
      DO 70 J=1,NCOL
      K=IVAL(J)
      GO TO (61,62,63,64,65,66,67),K
   61 CVAL(J)=B1(I)
      GO TO 70
   62 CVAL(J)=B2(I)
      GO TO 70
   63 CVAL(J)=B3(I)
      GO TO 70
   64 CVAL(J)=B4(I)
      GO TO 70
   65 CVAL(J)=B5(I)
      GO TO 70
   66 CVAL(J)=B6(I)
      GO TO 70
   67 CVAL(J)=B7(I)
   70 CONTINUE
  100 WRITE(IFILE,1030) I,(CVAL(K),K=1,NCOL)
C
C-----------PAGE PLOTS FOR SPECIFIED MATRICES-------------
C
  300 CONTINUE
      IF(INDEX(3,2).NE.0) CALL PGPLT2(IFILE,INDEX(3,2)-1,
     + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B2,NC2,LBL2)
      IF(INDEX(3,3).NE.0) CALL PGPLT2(IFILE,INDEX(3,3)-1,
     + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B3,NC3,LBL3)
      IF(INDEX(3,4).NE.0) CALL PGPLT2(IFILE,INDEX(3,4)-1,
     +  NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B4,NC4,LBL4)
      IF(INDEX(3,5).NE.0) CALL PGPLT2(IFILE,INDEX(3,5)-1,
     +  NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B5,NC5,LBL5)
      IF(INDEX(3,6).NE.0) CALL PGPLT2(IFILE,INDEX(3,6)-1,
     +  NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B6,NC6,LBL6)
      IF(INDEX(3,7).NE.0) CALL PGPLT2(IFILE,INDEX(3,7)-1,
     +  NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B7,NC7,LBL7)
      RETURN
 1000 FORMAT(1H1,12A10)
 1010 FORMAT(1H1)
 1020 FORMAT(1H0,4X,1HI,5X,7(1X,A10,A5)//)
 1030 FORMAT(1X,I5,5X,7E16.8)
      END
```

```
      SUBROUTINE ONEOUT(ICMPLX,NPTS,ISKIP,INDEX,A,B)
      DIMENSION A(ICMPLX,NPTS),B(NPTS),INDEX(7)
*ONEOUT    RETURNS ONE MATRIX GIVEN A MATRIX
C-----------FIRST SET UP MATRIX-----------
      DO 100 I=1,NPTS,ISKIP
100   B(I)=VALUE(INDEX(1),A(1,I))
C
C---------HANDLE NORMALIZATION OPTION, IF REQUIRED-----------
C
      IF(INDEX(5)*INDEX(6).EQ.0) GO TO 300
C-----------DETERMINE NORMALIZING FACTOR (FACTOR)----------
      K=INDEX(6)
      GO TO (220,230,240),K
220   J=ISKIP*((NPTS-1)/(2*ISKIP))+1
      FACTOR=B(J)
      GO TO 250
230   FACTOR=B(1)
      DO 235 I=1,NPTS,ISKIP
235   FACTOR=AMAX1(FACTCR,B(I))
      GO TO 250
240   FACTOR=B(1)
      DO 245 I=1,NPTS,ISKIP
245   FACTOR=AMIN1(FACTOR,B(I))
250   CONTINUE
C---------------NORMALIZE ARRAY-----------------------
      DO 270 I=1,NPTS,ISKIP
      IF(INDEX(5).EQ.1) B(I)=B(I)-FACTOR
270   IF(INDEX(5).EQ.2.AND.FACTOR.NE.0.) B(I)=B(I)/FACTOR
C
C---------COMPUTE NORMALIZED AREA, IF REQUIRED--------------
C
300   IF(INDEX(7).EQ.0) GO TO 999
      AREA=0.
      ICENT=(NPTS+1)/2
      DO 350 I=1,NPTS,ISKIP
      IF(INDEX(7).EQ.1) AREA=AREA+B(I)
      IF(INDEX(7).NE.1) AREA=AREA+B(I)*ABS(FLOAT(I-ICENT))
      B(I)=AREA
350   CONTINUE
      DO 370 I=1,NPTS,ISKIP
      B(I)=ABS(2.*B(I)/B(NPTS)-1.)
370   CONTINUE
999   RETURN
      END
```

```
      SUBROUTINE LBLPOS(NCX,LBLX,ISTRT,ILBL)                      9740
      DIMENSION LBLX(1),ILBL(21)                                  9760
*LBLPOS    LABEL POSITICNING ROUTINE FOR ALLOUT                   972.
      DATA IBL/1H /                                               9780
      ILBL(ISTRT)=LBLX(1)
      IF(NCX.GT.10) ILBL(ISTRT+1)=LBLX(2)
      IF(NCX.LE.10) ILBL(ISTRT+1)=IBL
      RETURN                                                      9960
      END                                                         9980
```

APPENDIX F

GLOSSARY OF PRIMARY SSCP(ECS) NAMES

ALLOUT	Subroutine by which GPOP output is produced
AMPINT	Array for defining initial amplitude of waves
AREA21	Subroutine for computing area of a wave
ASR	Input variable defining pseudo-three-dimensional parameter
CASE	Input variable used for titling output
CASENO	Namelist block name for describing number of cases to be analyzed
CAVITY	Namelist block name for printing cavity description
CSCALE	Subroutine for determining printer plot scale increments
DIA1	Input variable defining diameter of output mirror
DIA2	Input variable defining diameter of back mirror
DXOLD	Array saving all DX values for each step of the last half-pass through the medium
GAIN	Array of gain and refractive index variations
GAINA	Subroutine defining GAIN array for medium propagation
GZERO	Input variable initalizing g_o for GAINA
IFILE	Input variable initializing normal output file code
INFOUT	Array defining output option for near field printout
IRCODE	Input variable describing file code from which restart information is to be read

IROUT	Input variable describing file code to which restart information is to be written
IRTAG	Input variable describing pass number of wave(s) to be taken as restart information
LBLPOS	Subroutine positioning column heading label for GPOP
MEDIUM	Namelist block name for printing medium description
MIRROR	Subroutine for reflecting waves from mirror
MIRRRS	Namelist block name for printing mirror descriptions
NCASES	Input variable setting number of cases t be analyzed
NORM2D	Subroutine for preserving 2D Area
NPASS	Input variable setting number of passes for a case
NWAVES	Input parameters defining the number of propagating waves
NWDIM	Dimensioning parameter for maximum number of waves that can be handled by the SSCP(ECS) or SSCP
NX	Input parameter defining the number of mesh points along the x-direction
NXC1	Computed parameter defining the number of x-intervals across the output mirror at start of pass
NXC2	Computed parameter defining the number of x-intervals across the back mirror
NXCOUT	Computed parameter defining the number of x-intervals across the output mirror at end of pass
NXDIM	Dimensioning parameter for maximum number of mesh points along x that can be handled by the FICP
NZDIM	Dimensioning parameter for maximum number of last-pass intensity stores possible
ONEOUT	Subroutine for defining vector from GPOP options
OUT1-OUT7	Arrays used by GPOP for defining values to be produced

P50GAI	Subroutine for computing set of gain values at a z-location
P50GET	Subroutine for retrieving a value from the last pass intensities matrix (SO)
P50INT	Subroutine for reducing the expanded waveform(s) to begin another pass
P50MED	Subroutine for propagating one way through a medium
P50SBS	Subroutine for propagating through an empty cavity (no medium) region
PGPLT2	Subroutine producing GPOP printer plot
PR51	Main program of SSCP(ECS)
PWROUT	Subroutine computing near field and output power
RAT3DA	Subroutine for preserving 3D Area
RCURV1	Input parameter defining the radius of curvature for the output mirror
RCURV2	Input parameter defining the radius of curvature of the back mirror
REFL1	Input parameter defining the power reflectivity of the output mirror
REFL2	Input parameter defining the power reflectivity of the back mirror
RSTART	Subroutine forming an input wave by restarting a previous run
RUNOPT	Namelist block name for printing run options
SETMIR	Subroutine for setting up a mirror vector
SO	Array storing last-pass intensity values
SONEW	Array storing current intensities until they can be stored
SOTOT	Array storing sum of old and new intensities

T	Array (dummy) used in propagation routines
TILT1	Input parameter defining mirror tilt angle of output mirror
TILT2	Input parameter defining mirror tilt angle of back mirror
TLOSS1	Input parameter defining power loss of output mirror
U	Array storing propagating waveforms
V	Array (dummy) used in propagation routines
VR1	Virtual image source radius of curvature for output mirror
VR2	Virtual image source radius of curvature for back mirror
VALUE	Subroutine computing one of several values for complex numbers
WAVES	Namelist block name for printing propagating wave characteristics
WOMEGA	Array defining gaussian ω for each input wave
X	Array defining physical position of each field point
XCENTR	Input parameter defining the x-value for the center of the propagation array
XIZERO	Input parameter defining I_o for GAINA
XKZERO	Array storing K_o, or $2\pi/\lambda$, for each wave
XLAMDA	Array defining λ for each wave
XMIR1	Array representing output mirror
XMIR2	Array representing back mirror
XWIDTH	Input parameter defining minimum spatial extent (in x) of the beam

ZLEN	Input parameter defining distance between the output and back mirrors
ZLENMD	Input parameter defining the length (along z) of the gain medium
ZMDLOC	Input variable describing position of medium in cavity

DISTRIBUTION LIST

(Chemical Laser Technology)

ADDRESSES			COPIES (Special)
1.	Commanding General U. S. Army Missile Command Redstone Arsenal, Alabama 35809 ATTN: AMSMI-RK	(Dr. Rhoades)	20
		(Dr. Wharton)	1
	AMSMI-RR	(Dr. Hallowes)	1
		(Dr. Barr)	1
		(Mr. Jennings)	1
	AMSMI-RB		4
2.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314		20
3.	Lockheed Missile & Space Company Huntsville Research & Engineering Center Post Office Bix 1103 ATTN: Mr. John Benefield Huntsville, Alabama 35807		3
4.	Dr. James G. Skifstad School of Mechanical Engineering Purdue University Lafayette, Indiana 47907		1
5.	Air Force Weapons Laboratory ATTN: AFWL-LRT		2
	AFWL-SYT Kirtland Air Force Base, New Mexico 87117		1